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JOURNAL OF THE
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Volume 5 MARCH, 1938 Number 5

The Fundamental Principles of the N.A.C.A. Cowling

THEODORE THEODORSEN, ***National Advisory Committee for Aeronautics***

Presented at the Aerodynamics Session, Sixth Annual Meeting, I. Ae. S. January 26, 1938

Introduction

THE present paper presents a discussion of the underlying principles of operation of the N.A.C.A. cowling. The information upon which the following analysis is based was obtained from large-scale wind-tunnel tests (Fig. 1) conducted systematically on a large variety of cowling combinations during 1935–36. The history of the early development of the N.A.C.A. cowling and the status of the design information prior to 1935 is well given in E. P. Warner's *"Airplane Design,"* pages 368–382. Detail technical information of this latest investigation has also been made available through the regular N.A.C.A. reports.[1,2,3,4] Therefore no attempt shall be made to go into the history, nor to give many details of the results. On the other hand an attempt shall be made to present the basic information gained in their relation to our present knowledge of aerodynamics. Many results become obvious, once their nature has been established and the facts have been made to fit the laws of nature, as they are seen. A few of the more essential or illustrative results and the main conclusions will be presented.

As a preliminary orientation for the following discussion, it is pointed out that it is useful to separate the problem into as many distinct parts as possible. To start with, the cowling itself actually performs two distinct functions: (1) it provides a streamline enclosure of minimum drag, and (2) it provides a certain pressure difference across the engine. It shall be shown how the drag coefficient correspondingly consists of a form drag coefficient and a cooling drag coefficient and rules will be given as to how to estimate both with sufficient accuracy. Several constants will be introduced relating to specific physical quantities and essential relationships between the quantities involved, governing the design and operation of an N.A.C.A. cowling, will be presented.

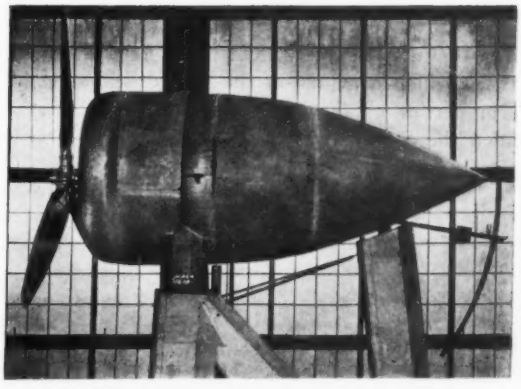

Fig. 1. Photograph of full-scale test installation.

Conductivity

One readily recognizes the fact that as far as the aerodynamic performance of the cowling is concerned, the engine might just as well be replaced by a certain fixed resistance. To indicate the magnitude of this resistance, or rather its reciprocal, the term con-

ductivity, designated by K, has been introduced for convenience.

There is the relation

$$\Delta p = \xi\,(v_1^2/2g)\gamma$$

where Δp is the pressure drop across the resistance
v_1, *any representative* velocity
γ, specific weight
ξ, a fixed constant

also

$$\Delta p = \xi \cdot q_1$$

where

$$q_1 = (v_1^2/2g)\gamma$$

If F_1 is the *representative* cross-section, for the volume passing through in unit time

$$Q = F_1 \sqrt{2gq_1/\gamma} = F_1 \sqrt{2g\Delta p/\gamma\xi}$$

To obtain non-dimensional relations another volume given by the full stream velocity and the cross-section of the nacelle is introduced.

$$Q_R = F\sqrt{2gq/\gamma}$$

dividing:

$$Q/Q_R = (F_1/F)\sqrt{q_1/q} = (F_1/F)\sqrt{\Delta p/(\xi \cdot q)} = (F_1/F)(1/\sqrt{\xi})\sqrt{\Delta p/q}$$

The quantity $(F_1/F)(1/\sqrt{\xi})$ may be seen to be a *constant* which depends on the geometrical and physical properties of the engine; this is what has been termed the conductivity K.

Hence

$$Q/Q_R = K \cdot \sqrt{\Delta p/q}$$

where

$$K = (F_1/F)(1/\sqrt{\xi})$$

Experimentally then, K may be obtained simply by measuring volume passing through for a given pressure drop. Fortunately this experiment is not absolutely necessary since it is found that the value ξ lies within fairly narrow limits. In fact $1/\sqrt{\xi} = 0.65$ for sharp-edged holes and is found to be of about the same value for baffles with poor exit expansion and to reach about 0.9 for well-designed expanding exits, as in Fig. 6.

The following simple rule may therefore be expressed: *The conductivity of the engine is a number expressing the area of the free passage in ratio to the nacelle cross-section. The free passage may be considered equal to about* 60 *to* 90 *percent of the free minimum cross-section.*

For single-row engines the value of the conductivity is about 0.05 and probably reaches 0.07 for the more modern, deeper fins. For double-row engines the values are about double since the flow is in parallel.

For many purposes of experimentation on the cowling, the engine may readily be replaced by an orifice plate. For instance, for a 50 in. diameter nacelle each one inch hole would represent a conductivity of $(1/2500) \times 0.65$ and 250 holes would give the approximate conductivity of a single-row engine, or 0.065.

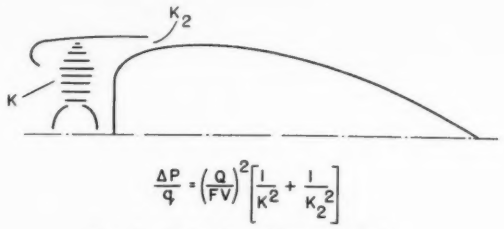

FIG. 2. Equation of flow regulation.

FLOW REGULATION

Referring to Fig. 2, one may write $\Delta P = \Delta p + \Delta p_2$, where ΔP is the total available pressure difference created by the cowling, or the static pressure ahead of the engine minus the static pressure in the exit slot. The static pressure in front was found to be almost exactly $1q$ for the smaller conductivities of the one-row engine, and about $0.9q$ for a conductivity corresponding to a modern two-row engine. The static pressure behind may be put equal to zero or -0.1 for well-designed and efficient exits. Thus ΔP *is for all practical purposes equal to one velocity head* q *in good cowling designs.* It should be noted that ΔP is not the pressure difference across the engine, but the *total* created by the cowling. Part of the available pressure, namely Δp_2, is used to get the air through the relatively narrow exit slot.

The friction loss in the exit slot of normal good design is found to be negligible, so that

$$\Delta p_2 = \gamma\, V_2^2/2g$$

Introduce $V_2 = Q/A_2$, where Q is the volume in unit time and A_2 the effective cross-section of the exit slot. Further, put $A_2 = K_2 \cdot F$ where F, as above, is the representative cross-sectional area of the nacelle and K_2 the "conductivity" of the exit slot. With $q = \gamma\, V^2/2g$ this gives

$$\Delta p_2/q = (Q/K_2FV)^2$$

Using the relation already developed for Δp, the pressure drop across the engine,

$$\Delta P/q = (Q/FV)^2\,[(1/K^2) + (1/K_2^2)]$$

This equation has been called the equation of flow regulation. It is the basic equation governing the flow of the cooling air. As could have been expected, the relation was found to hold for the entire range; in other words, there is no appreciable Reynolds Number effect on K, K_2, or the available pressure.

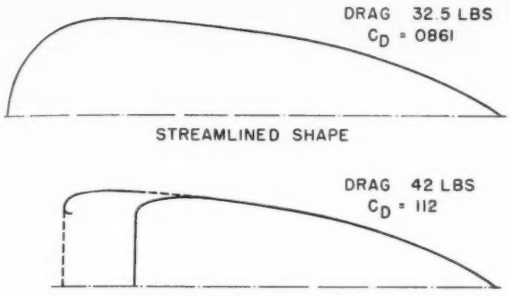

FIG. 3. Basic shape. N.A.C.A. cowling tests. In this figure C_D should equal .0861 and .112, respectively, for the upper and lower figures.

The left side of this equation gives the available pressure in non-dimensional form; its value is, furthermore, for all practical purposes, equal to unity. The first term on the right side is the square of the flow, also in non-dimensional form, simply as the fraction of the air column FV. The last term on the right side is seen to represent two resistances in series, also non-dimensional.

Take an example to show the use of this equation. Assume an engine with a conductivity of $K = 0.15$, cooling satisfactorily at 20 lbs. per sq.ft. pressure difference across the baffles. What should be the area of the exit slot at 300 m.p.h. to prevent waste of cooling power? First, for the pressure drop across the engine, one has

$$\Delta p/q = (Q/FV)^2 \cdot (1/K^2)$$

or

$$(Q/FV)^2 = (\Delta p/q) \cdot K^2 = (20/230) \cdot 0.15^2 = 0.00195$$

and from the main equation

$$1 = 0.00195\ [(1/0.15^2) + (1/K_2^2)]$$

which gives $K_2 = 0.046$, or an opening of $A_2 = 0.046\ (\pi/4)\ D^2$ where D is the cowling diameter. It is seen that this opening corresponds to a little more than $^1/_2$ in. effective gap for conventional cowling sizes. Again, referring to the equation of flow regulation, if the engine requires 20 lbs. per sq.ft. across the engine for continuous cooling, the required exit opening gradually increases as the air speed is decreased. At 125 m.p.h. the conductivities K and K_2 are approximately equal, the required effective gap on a 50 in. diameter cowling being then

$$(1/4) \cdot 50 \cdot 0.15 = 1.9 \text{ in.}$$

At still lower air speeds the simple widening of the exit gap is no longer effective; a speed of 100 m.p.h. is in the present example the lower limit.

The only other possibility for increasing the cooling flow is to increase the generated pressure $\Delta P/q$. This calls for very special measures. It must be realized that even for a flat circular disk the average pressure differential is only about $1.2\,q$ in spite of the enormous drag. The use of cowl flaps is an attempt in this direction. The present investigation showed that flaps actually increase the $\Delta P/q$ from unity, its normal value, to a maximum of 1.3. This would permit a lowering of the minimum air speed in the above example to a little less than 90 m.p.h. The increase in drag is, however, considerable. Another attempt to increase the available $\Delta P/q$ has been undertaken in an N.A.C.A. nose-cowl investigation, the early results of which are given in Technical Report No. 595.[4]

PUMP EFFICIENCY

So far the drag associated with the cooling has only occasionally been referred to. It is realized that it is not only necessary to have sufficient head available to cool the engine but that this cooling must be done at the minimum expense of power. For this consideration the concept "*pump efficiency*" has been introduced. The pump efficiency is simply the ratio of the work expended for cooling, $Q\Delta p$ in previous notation, divided by the work due to the increased drag of the cowling, $D - D_0$, at the velocity V, or

$$\eta_p = Q\Delta p/(D - D_0)V$$

It is interesting to remark at once that the cowling constitutes a remarkably good pump. Efficiencies of around 90 percent may be regarded as normal. There is, of course, a certain ambiguity in regard to the definition of D_0, which is considered to be the drag of a similar cowl performing *the function of streamlining the power plant but not the function of cooling.* (See Fig. 3.)

Since the engine cowling nacelle is not usually of the best streamline form, this imperfection in form must not be charged against the cooling. The quantity D_0 is therefore the drag of the basic form of the same general contour as the cowling considered, but with the cooling ducts closed by the best possible fairings. This "basic shape" by stippled lines closing the frontal cavity and the exit ducts is shown in Fig. 3.

By referring again to Fig. 3, it can be seen that the drag of the "flat-nosed" cowling at 100 m.p.h. in the wind tunnel is 42 lbs. as against 32.5 lbs. for the semi-spherical nose shown above. However, the difference is not at all a total loss, as shall be seen later. The value of D_0 of 42 lbs. is therefore used in calculating pump efficiencies. In the tests referred to, it soon became evident that the pump efficiency is an excellent figure of merit; and further, that its value depends largely on the flow condition at the exit. A design embodying a smooth external contour line is always distinctly superior. Also, it was found that a large exit velocity is favorable. The dependence on the exit velocity is, however, not large, unless this approaches zero.

The formula for the pump efficiency shall now be rewritten in a somewhat different form

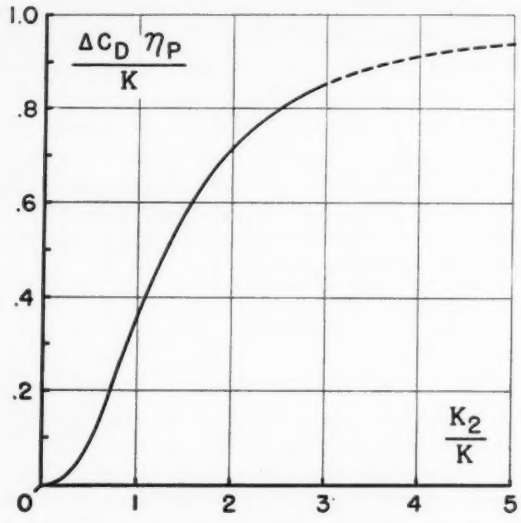

FIG. 4. Drag coefficient *versus* conductivity. Note that the equation of the ordinate should read: $\Delta C_D \eta_p / K$.

$$\eta_p = Q \Delta p / (D - D_0) V$$

By putting

$$D - D_0 = \Delta C_D F q$$

where ΔC_D is the increase in the drag coefficient due to cooling, as before referred to the nacelle cross-section. Also introduce

$$Q/VF = \sqrt{\Delta p/q} \cdot K$$

Then

$$\eta_p = (1/\Delta C_D)\, K \cdot (\Delta p/q)^{3/2}$$

or also

$$\Delta C_D = (1/\eta_p)\, K \cdot (\Delta p/q)^{3/2}$$

From the equation of flow regulation for conventional cowlings ($\Delta P/q = 1$)

$$\Delta p/q = \frac{1/K^2}{(1/K^2) + (1/K_2^2)} = \frac{1}{1 + (K/K_2)^2}$$

and finally for the cooling drag coefficient

$$\Delta C_D = (1/\eta_p) \cdot K\, [1 + (K/K_2)^2]^{-3/2}$$

This relation gives a very convenient formula for the drag increase. The relation lends itself to a plot of the form

$$(\Delta C_D \cdot \eta_p)/K = 1/[1 + (1/p^2)]^{3/2}$$

where $p = K_2/K$ is simply the ratio of the exit opening to the equivalent free engine flow cross-section as already defined.

Fig. 4 gives this relation in the form

$$(\Delta C_D \cdot \eta_p)/K = f(K_2/K)$$

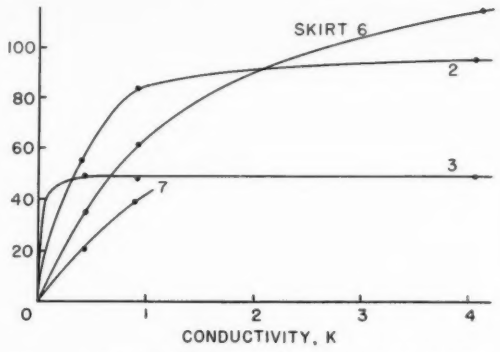

FIG. 5. Pump efficiency. N.A.C.A. cowling tests. The ordinate in the above figure represents percentages.

The value of η_p (for the optimum design) is somewhat dependent on the abscissa K_2/K. It is close to 100 percent, however, over most of the range, dropping to around 80 percent at $K_2/K = 3$ and dropping further beyond this point due to the low exit velocity. For inefficient exits, of course, these values do not apply. Typical test results on the pump efficiency are shown in Fig. 5. (See reference 1.)

As an example, refer to the case already given with $K = 0.15$, $K_2 = 0.15$. From the plot one immediately obtains

$$\Delta C_D\, \eta_p / K = 0.353$$

or using $\eta_p = 0.90$

$$\Delta C_D = 0.353 \cdot 0.15/0.90 = 0.059$$

This value is probably within ±10 percent, provided the design is the best possible.

MECHANISM OF FRONTAL COOLING

The body shown in the lower part of Fig. 3 represents the basic form of the nacelle used in this investigation. Its drag coefficient is $C_D = 0.112$; removing the flat plate (shown by stippled line, Fig. 3) and thus exposing the frontal cavity to the air stream, increases the drag coefficient to $C_D = 0.119$. These figures compare with a drag coefficient of only 0.086 found for the same body equipped with a spherical nose as shown in the upper part of Fig. 3. This drag increase of 0.026–0.033 over the drag of a better streamlined body is typical of the normal present-day cowling, and can consequently be partly reclaimed by using a more spherical nose with a longer propeller shaft. However, this loss manifests itself in a large turbulence of the air striking the front of the engine, and is thus responsible for the excellent cooling observed on the frontal unbaffled halves of the cylinders.

In fact, at speeds below 150 m.p.h. it is probably not possible to provide a more efficient cooling by any other means. Returning to the example, it was found that the normal cooling drag ΔC_D was equal to 0.059 at

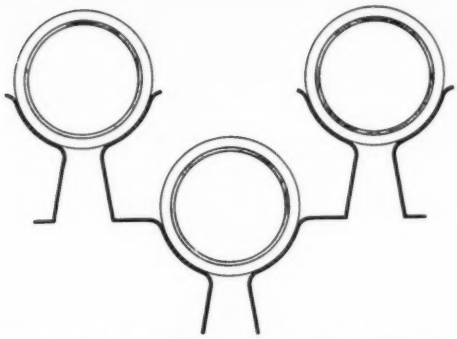

FIG. 6. N.A.C.A. baffle design for double-row radial.

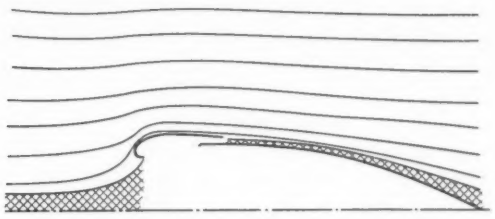

FIG. 7. Streamlines. N.A.C.A. cowling tests.

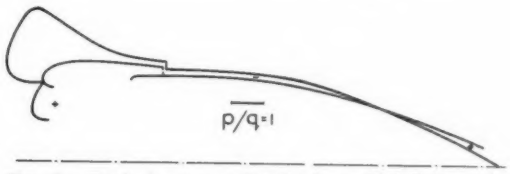

FIG. 8. Typical pressure distribution. N.A.C.A. cowling tests.

a speed of 125 m.p.h. This drag accounts for the cooling within the narrow baffle channels but hardly for any of the front cooling, which fact can be demonstrated by a simple experiment. The cost of the frontal cooling may therefore be considered to be no more than the drag difference 0.033. To recapitulate: The poor shape of the front cowling contours is responsible for a drag increase of 0.033, manifesting itself as a result of an unstable and turbulent flow in front of the cowling resulting, of course, in an earlier transition into fine-grain surface turbulence; but this unstable and turbulent flow in front of the engine may at the same time be credited with a large heat-absorbing ability. Comparing the two figures just mentioned, one is tempted to state that the front cooling is as efficient as the cooling in the ducts. It must be noticed, however, that the cooling drag coefficient ΔC_D may be reduced as much as desired at higher air speeds, so as to provide just the right amount of pressure differential, but that that there are no provisions for decreasing the drag relating to the flat nose. For high speeds a better streamlined nose, permitting some sort of regulation, is obviously desirable.

A direct effect of recognizing the importance of the front turbulence is the baffle design shown for a double-row engine in Fig. 6. Note the spacious entrance to the rear bank. The baffle design shall otherwise be considered to be beyond the scope of this paper.

Effects of Propeller

For normal flight conditions the effect of the propeller is found to be a minor one. The main table in reference 1 shows that the propeller causes a slight decrease in pump efficiency compensated by a corresponding slight improvement in the cooling. The net effect of the propeller on the main flow is a slight convergence of the streamlines in front of the cowling, as compared with the flow around the cowling alone, and by a comparatively small velocity increase. This slight convergence of the frontal streamlines due to the propeller may paradoxically convert a poor cowling (nose 1 in reference 1) into a comparatively good one; that is, the presence of the propeller actually decreased the drag of the cowling. This fact is, of course, only of incidental interest insofar as it confirms the expected change in the flow lines. The actual appearance of the streamlines with propeller on is shown as an illustration in Fig. 7. Note the very divergent flow in front of the cowling.

At low air speeds, particularly for the case of ground cooling, there is quite a different problem. The inherent deficiency of the normal propeller to produce a pressure differential near the hub is here a serious problem. As a measure of the blower action of the propeller, the *blower constant* $\Delta p/n^2$, has been introduced, which is actually the resulting pressure differential available for cooling behind the propeller in lbs. per sq.ft. at a speed of one r.p.s. As expected, the blower constant depends on the size and perfection of the shank cross-section immediately in front of the cowling and also on the diameter of the opening. For detail information, the reader is referred to reference 2. It will just be mentioned that the value of $\Delta p/n^2$ in lbs./ft.^{2} r.p.s.^{2} ranges from a minimum of 0.01 observed for a propeller with a poor shank section on a cowling with the smallest front opening to a maximum of 0.04 for a propeller with a pronounced airfoil section near the hub on a cowling with a front opening somewhat larger than the one considered optimum for normal conditions of flight. The latter showed a constant of 0.036.

Other Problems and Further Research

Another investigation which has been carried on in parallel is the development of the nose cowling, so called to indicate that the exit is located near the front of the cowling. The typical pressure distribution shown for a conventional cowling in Fig. 8 reveals the existence of a large negative pressure near the front. Preliminary tests[4] employing, however, very small values of K, showed large pump efficiencies. Realizing the possibility of utilizing this greater pressure dif-

ferential for cooling, the work on the nose cowling has been continued. The final outcome will be available through the regular reports.

The use of much larger engine conductivities employed on recent design calls for a certain extension of the original research here reported. The possible interference effect of the cooling air and the "flat" nose on the characteristics of a wing of which the nacelle is an integral part is also an important problem, as of course the nacelle is expected to merge into the wing with the greatest possible perfection in all respects.

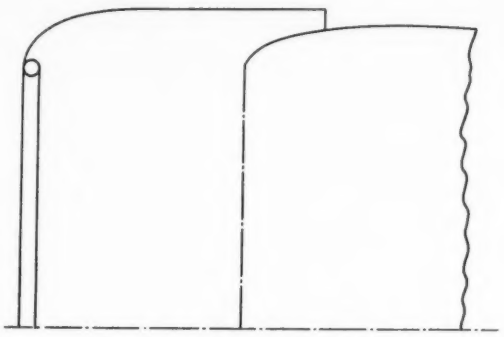

FIG. 9. N.A.C.A. cowling design.

GENERAL CONSIDERATIONS OF COWLING DESIGN

As a summary based on the experience gained in the N.A.C.A. cowling investigation, the essential design considerations shall be given briefly.

(1) *Nose design.* Not critical; should on the whole resemble the design given in Fig. 9, which is the number 7 of the original test series. The angle of the front camber line should be of the order of 45° with the axis. The area of the opening should merely be as large as consistent with these requirements.

(2) *Skirt design.* Rather critical; the area is to be determined by the equation of flow regulation and is consequently dependent on the engine conductivity and the pressure required across the engine. The skirt edge should not project into the external airstream but permit the external streamlines to remain smooth, nor should the edge project inward. The opening should therefore be formed by means of the inner cowl to permit a gradual velocity increase from the low velocity behind the engine. The mean flow line must be essentially parallel to the external flow lines, or at least not point too much outward at the point of exit. The skirt design should embody some provision for regulating the flow of cooling air, to prevent excessive losses at high speed, preferably by mechanical means for changing the location or contour of the inner cowl so as to increase or decrease the exit conductivity as conditions require.

The general appearance of the N.A.C.A. cowling is finally indicated in Fig. 9.

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Book Review

Hydro- and Aerodynamics, by S. L. GREEN; Sir Isaac Pitman & Sons, Ltd., London, 1937; 166 pages with index, $3.50.

This is an excellent and concise treatment of classical hydrodynamics which includes the traditional development of the equations of motion, application of the complex variable to conformal transformation, the theorems of flow and circulation including the Kutta-Joukowski construction for airfoils, vortex motion, and surface waves. This material, usually found in texts on hydromechanics, is supplemented by chapters on three dimensional flow of a perfect fluid, the steady motion of a viscous fluid (Navier-Stokes equation), boundary layer equations, laminar flow (Blasius' solution), and turbulent flow.

In general, the treatment is that of the applied mathematician with little or no physical interpretation or discussion of experimental evidence. The book is concise and straightforward. The numerous examples and the absence of a bibliography or references to original papers characterize it as a text for class room use, rather than a reference volume.

This reviewer is unable to say that he has read the text critically as the material presented covers too wide a scope, but from sampling a few chapters, it appears that this text is a simplification and abridgment of Lamb and about equivalent to Ramsey with the addition of the more modern concepts associated with the names of Kutta, Joukowski, Prandtl, and Blasius. As such, it is an excellent statement of the theoretical basis of the mechanics of incompressible fluids. J. C. HUNSAKER

Supercharging a Pressure Cabin Airplane

ALFRED H. JOHNSON,* *Air Corps, Materiel Division, Wright Field*

Presented at the Air Transport Session, Sixth Annual Meeting, I. Ae. S.
January 27, 1938

Introduction to High Altitude Flight Session†

Before introducing the speakers that have been scheduled to read papers in this session, your attention will be invited to a brief general survey of the problem under discussion.

To begin with, the title of this session might well be changed so that it would fit more exactly the precise ends toward which the attention of this group is for the moment directed. Instead of referring to *High Altitude Flight*, it might be closer to practical aims if the expression *High Level Operation* were used. Under the loose category of *High Altitude Flights* are included all the dashes to high altitude that have hitherto been made for records, for science, for glory, or as a necessary part of a military program. The predominant dimension of these interesting and colorful flights has been vertical—"up" and, almost immediately, "down." The predominant circumstances have been discomfort and danger.

High Level Operation can best be described as the addition of useful horizontal dimensions to the limited vertical movement involved in previous high altitude flying. Conversely, it might be described as the addition of a greater vertical dimension to the limits bounding present commercial and military operations.

Altitude flights of the past have been carried out in special airplanes or balloons, by specially selected and prepared individuals and under circumstances of great—almost unbearable—discomfort and of tremendous risk. All of this work has been valuable and intensely interesting both from a scientific and a human standpoint. But it has been adventure in the purest sense—the exploration of the unknown and mysterious by picked individuals in special and intriguing equipment.

This group is to consider the technical aspects of actually carrying out every day operation at high levels; levels not hitherto visited excepting by the stratosphere and sub-stratosphere explorers on their way up or down.

The position of the Army Air Corps in this matter must be made clear inasmuch as a large part of the material to be presented at this session comes from the Materiel Division. The Air Corps is exploring the situation—not expounding or urging on any one else a new development. The work that has been done is part of the program to look into and examine all possible expansions of mobility—which, after all, in one form or another, is the stock in trade. Therefore, the question as to whether commercial carriers should go to high levels is one for these carriers to decide from their three well-known and familiar standpoints: safety, economy, and effectiveness.

The Army has developed *one* method of operating at high levels, over long distances and at increased speeds, with a minimum of discomfort to passengers or of strain on the crew, but at the expense of a certain increase in weight and cost of the aircraft. The Air Corps feels that the experimental program carried out at the Materiel Division with the help of John E. Younger of the University of California and of the Lockheed Aircraft Corporation, together with an increasing amount of sound development work in the industry, has now progressed to the point where pressure cabin operation has been shown to be entirely possible and the construction of practical, effective pressure cabin aircraft to be well within the capabilities of the established aircraft industry in the United States.

THIS paper covers briefly the general problems encountered in supercharging engines and cabins for high altitude airplanes and includes conclusions reached to date as a result of Air Corps testing of the XC-35 sub-stratosphere airplane which was built by the Lockheed Aircraft Corporation for the Air Corps. An effort will be made to point out the lines of development which will have to be completed before operation of pressure cabin airplanes at high altitude becomes practical.

Engine Supercharging

It appears that the first step in the use of pressure cabin airplanes will be to increase the operating ceiling from 12,000 or 14,000 ft. up to 20,000 ft. This step will necessitate very little further development in engine supercharging unless operators require that the engine be capable of developing full rated power at the 20,000 ft. level. Present engines being used on commercial transports have critical altitudes of from 5000 to 10,000 ft. A few have two-speed blowers which have a critical altitude slightly above this range. Several of our military engines are now available with ratings up to 14,000 ft., and with present development of two-speed and two-stage supercharging, engines with critical altitudes of 15,000 to 17,000 ft. could be made available on very short notice. These engines will be capable of developing cruising power at the 20,000 ft. level and slightly above. It will be noted that no mention has been made above of the use of the exhaust driven turbo-supercharger. It is the author's belief that for cruising operation up to 20,000 ft., the mechanically driven two-speed and two-stage superchargers in their present stage of development are superior economically and in simplicity to the turbo-supercharger with its attendant complication in installation of intercoolers, regulators, and special fuel systems. For cruising operation up to 20,000 ft. the use of intercoolers on two-speed superchargers should not be necessary and our present fuel systems with slight improvements should be entirely satisfactory.

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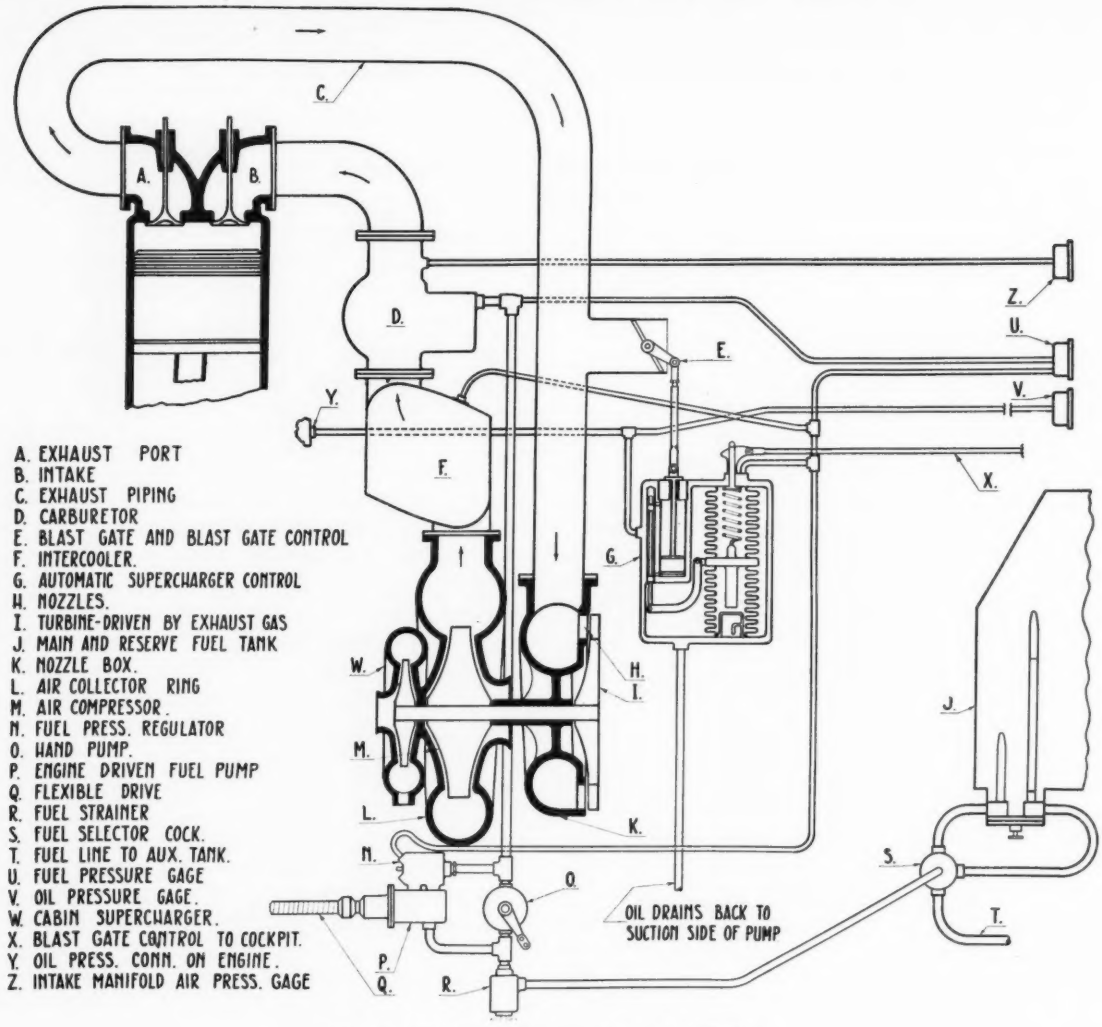
A. EXHAUST PORT
B. INTAKE
C. EXHAUST PIPING
D. CARBURETOR
E. BLAST GATE AND BLAST GATE CONTROL
F. INTERCOOLER.
G. AUTOMATIC SUPERCHARGER CONTROL
H. NOZZLES.
I. TURBINE-DRIVEN BY EXHAUST GAS
J. MAIN AND RESERVE FUEL TANK
K. NOZZLE BOX.
L. AIR COLLECTOR RING
M. AIR COMPRESSOR.
N. FUEL PRESS. REGULATOR
O. HAND PUMP.
P. ENGINE DRIVEN FUEL PUMP
Q. FLEXIBLE DRIVE
R. FUEL STRAINER
S. FUEL SELECTOR COCK.
T. FUEL LINE TO AUX. TANK.
U. FUEL PRESSURE GAGE
V. OIL PRESSURE GAGE.
W. CABIN SUPERCHARGER.
X. BLAST GATE CONTROL TO COCKPIT.
Y. OIL PRESS. CONN. ON ENGINE.
Z. INTAKE MANIFOLD AIR PRESS. GAGE
OIL DRAINS BACK TO SUCTION SIDE OF PUMP

FIG. 1. Typical turbo-supercharger installation.

In levels from 20,000 ft. on up, the turbo-supercharger appears at the present to be the most suitable means of maintaining engine power. It has been the experience of the Air Corps that the critical altitude of a turbo installation has not been in the turbo itself but in the intercooler and fuel system installation. Intercoolers have given some trouble due to cracks, leaks, and difficulty in obtaining sufficient intercooling without excessive pressure drop through them. The Air Corps now has under way a development program on intercoolers with a view to determining more suitable methods of construction and materials to be used in them. The fuel systems of airplanes designed to fly above 20,000 ft. have given trouble due to vapor lock. The vapor-lock troubles were caused by high vapor pressure fuel, long fuel lines, and to the necessity of relieving some fuel back into the suction side of the system in order to obtain proper fuel pressure control. As a result of an investigation just completed at the Materiel Division, a system was worked out which gave satisfactory control of fuel pressure with present standard fuels up to 40,000 and 50,000 ft. It was determined that the following should be observed in designing a fuel system for operation with a turbo-supercharger at high altitude:

(1) The fuel pumps must be below the fuel supply.

(2) The fuel lines to the fuel pump should be of such size and the routing so direct that there will be a free flow of fuel to the pump inlet equal to at least the maximum demands of the engine.

(3) There should be no relieved fuel. The speed of the fuel pump should be so governed that the pump delivers the exact amount demanded by the engine at a given pressure. (Note: The Air Corps accomplished this by use of a variable speed hydraulic motor; the speed being governed by fuel pressure.)

Fig. 1 shows a diagram of a typical turbo-supercharger installation. It will be noted that the regulator is equipped with a cam control so that the carburetor

air intake pressure may be controlled to any desired value while in flight. On the early installations the carburetor entrance pressure was maintained constant at approximately sea level pressure. The new regulators permit considerable reduction in back pressure at cruising powers.

Supercharging the Pressure Cabin

Present commercial transports and military aircraft are capable of operation at altitudes considerably above the present levels permitted by regulations but it is known that long periods of operation even at levels around 12,000 to 14,000 ft. have some ill effects on the crew and passengers. Pressure cabin airplanes will therefore be designed to maintain a pressure equivalent to approximately 8000 ft., and perhaps slightly below. From tests conducted at the Materiel Division it appears that ten cubic feet of air per minute per passenger is sufficient to keep the air clean and healthful. This amount of air, however, will not be sufficient for circulation purposes and the air in the cabin should be kept moving by some circulation system. It may be that the heating and ventilating systems can be combined. The amount of heat obtained by compressing ten cubic feet of air per minute per passenger may reduce the capacity of the heating system required but will not be sufficient to do away with a heating system.

For supplying the necessary air under pressure, two methods have been proposed: one, the use of a centrifugal blower mechanically or turbo driven; and the other, a mechanically driven Roots blower. The exhaust turbo-driven centrifugal blower was used by the Air Corps because it was the most suitable method available at the time and it was readily adaptable to the exhaust-driven engine supercharger. This type of installation has one major disadvantage in that the speed of the cabin supercharger varies with the main engine power output. It is therefore necessary to use considerable power when descending from high altitude. Due to the now almost universal use of constant speed propellers the mechanically driven centrifugal blower or Roots blower may be geared directly to the main engine and a small speed range is assured. A small speed range is important, especially when the centrifugal type is used. At the present time there are no mechanically driven cabin superchargers available and development of the two types should be started immediately. The Air Corps has contacted various interested parties in the industry and hopes to have specifications available shortly. To assure a margin of safety, two cabin superchargers should be used, each capable of meeting the cabin pressure and flow requirements.

The type of pressure control system will vary somewhat with the type of supercharger used but in any case, it should be automatic with provisions for manual control in emergency. Some of the automatic mechanisms which will be needed are: A device for closing all outlet air ducts in case of supercharger failure; an automatic cabin pressure regulating valve; automatic spring loaded valves of large area which will prevent excess pressure in event of failure of control mechanism and automatic means to prevent negative pressure in cabin relative to outside atmospheric pressure.

Pressure Cabin Requirements

Cabin pressure tightness in a supercharged cabin airplane is a considerable problem. A general requirement for cabin tightness should be that in case of complete supercharger failure the cabin should be so pressure tight that the airplane may descend from its maximum cruising altitude at 200 to 500 ft. per min. to a safe altitude for cruising without pressure, before the cabin pressure goes below a safe minimum. The greatest source of air leaks will be around doors and the air required to run de-icers and flight instruments. Leaks around doors may be eliminated by the use of inward opening doors. This is not a very desirable feature but some means could undoubtedly be developed for sealing them more perfectly or making them outward opening in emergency only. Present-day air pumps used to run the flight instruments and de-icers are of the suction type and their capacity and performance fall off rapidly with inlet depression which makes it almost mandatory for the inlet air to come from the pressure cabin when operating at high altitude. To eliminate the instrument air loss will require the development of pressure type instruments operating with a closed air system.

Another quite serious problem in pressure cabin operation is the development of a means of defrosting and de-icing the pilot's windshield both inside and outside. The thickness of glass required to stand cabin pressure safely prevents the de-icing by application of heat on the inside. A mechanical device or means of supplying heat on the outside of the windshield will be required.

Preliminary Tests

Before going into detail on the operation of the XC-35 airplane, it would probably be interesting to present some of the experiences encountered in the early flying and testing of this airplane. After certain flying by the Lockheed Aircraft Corporation to determine that the airplane flew satisfactorily as a normal airplane without pressure, a crew was sent from Dayton, Ohio, to conduct the official flying acceptance test. All were quite aware that similar tests conducted in Europe had ended disastrously and it was therefore planned to proceed cautiously. The first flights were to check the general flying qualities and were satisfactory except that the visibility from the pilot's cockpit was none too good. This was due to the fact that the windshields in the pilot's cockpit were of resinoid material and not very large and also to the fact that the pilot's canopy

was extremely faired into the fuselage in order to save structural weight. The material in the pilot's compartment windshield was changed after the first pressure flight testing, to three-quarter inch laminated plate glass which improved the visibility considerably. After the general flight tests were completed it was decided to subject the fuselage to pressure tests several times on the ground to test cabin tightness and to check the operation of the discharge and emergency valves. The first pressure test on the ground was amusing. The airplane was surrounded by a large number of curious observers anxious to see what would happen. The air seals around the doors and windows had not been completely adjusted and when pressure was applied to the cabin the many leaks emitted whistling sounds of varied pitch. The less curious observers started slowly leaving the building. As the pressure was increased each whistle turned to a screech and these observers increased their speed toward all exits. The pressure was increased to 15 lbs. per sq. in. and nothing more happened except that it was noticed that the windows were considerably bowed due to the pressure. This was rather disconcerting at first, but after all the leaks and seals had been adjusted and several trials of pressure at 15 lbs. per sq. in. were made, all were reassured and ready for the first flight test under pressure on May 25, 1937.

First Pressure Flight Test

Everyone who had anything to do with the development of the airplane was so confident that the airplane would be satisfactory that they wanted to go along on the first pressure flight test. Two or three applications were received for every seat in the plane, but six were all that were necessary to read the one hundred or more instruments with which the cabin was filled, so the flight was made with that number. Upon reaching 12,000 ft. the cabin superchargers were turned on and the flight continued. Some moisture started to condense on the windshield and it was also noticed that the airspeed shown by the airspeed meter was rapidly decreasing. Evidently, somewhere there was a leak from the cabin into the instrument static pressure line. However, by wiping the windshield quite often flight visibility was obtainable. At 20,000 ft. altitude there was a thin layer of clouds. The temperature had fallen until the moisture on the inside of the windshield was freezing, so that the ice had to be scraped off in order to see. At this point the airspeed meter showed minus 150 m.p.h., and since one could not see to fly in the clouds it was decided to call it a day and come down. At least a partially successful flight under pressure had been made and without the use of oxygen to 20,000 ft.

Subsequent Flight Tests

Several more flights were made adjusting instruments and testing the general operation of the airplane above 20,000 ft. On the highest flight, which was to 28,000 ft., a greater altitude could not be reached due to the loss in fuel pressure. Nothing very eventful happened on these flights, however, until one day an enterprising Lockheed engineer decided that Major Greene needed an assistant cabin operator and proceeded to show him and the rest of the personnel how effective the cabin supercharger controls could be. This engineer started operating levers like a switchman in a busy freight yard and all were being taken up and down three and four thousand ft. several times a minute. The heads of the passengers felt as though they were changing dimensions like the bellows of an old-fashioned blacksmith's blower. It did not take very long to put that engineer in one of the back seats. The next day no flights were made for all heads felt like the "morning after."

After a few minor changes in equipment and controls, the acceptance tests were completed and the flight back to Dayton was made at an altitude of 25,000 ft. At this altitude the plane cruised along fine at 210 m.p.h. and it was a pleasure to be up there in comfort instead of being cold and sucking on an oxygen tube. The trip back was uneventful but it was noticed that having the cabin supercharger driven by the exhaust gas was objectionable due to the fact that all variations in engine power had an effect on the cabin's supercharger and made it necessary to manually correct the position of the cabin supercharger controls each time an adjustment was made in any of the engine controls.

Cabin Superchargers

The Army XC-35 airplane is believed to be the first successful supercharged cabin airplane. The airplane resembles the Lockheed Electra very closely except for the fuselage which is circular in cross section. The pressure cabin is divided into two compartments; either one or both may be supercharged. The pressure compartment extends from the nose to the station just forward of where the tail surfaces are attached. The airplane is of conventional all-metal construction except that special attention has been paid to sealing all openings and riveted joints. It is powered with two 550 hp. Wasp engines equipped with turbo-superchargers. Each exhaust turbine wheel drives two centrifugal impellers on the same shaft, one impeller supplies the engine requirements and the other supplies cabin air. As originally designed, either cabin supercharger was capable of supplying 150 to 250 cubic feet of air per minute under pressure so in case of failure of either supercharger, the other was able to more than meet air flow requirements for a crew of six or more. In the original design, the cabin superchargers were designed to hold the cabin at 12,000 ft. with the airplane at 25,000 ft., but after the first series of tests it was decided to alter the supercharging system so that

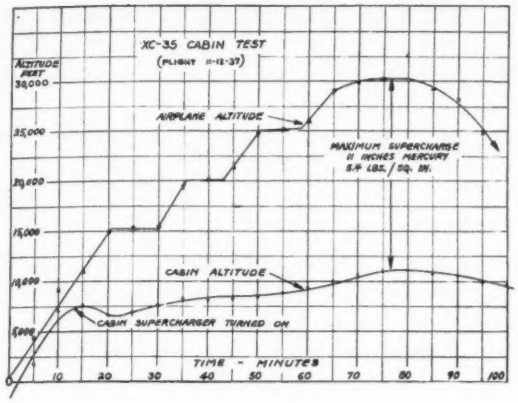

FIG. 2.

it would be possible to operate up to at least 30,000 ft. with a cabin pressure equivalent to 10,000 ft. or less. The system was therefore changed so that it was possible to connect the two superchargers either in series or parallel. With the superchargers in series it is now possible to control the cabin pressure over a much wider range and at higher altitude. Although the airflow was approximately halved it was still well in excess of minimum requirements and in case of failure of one supercharger or engine it is possible to change the system to parallel operation and obtain sufficient pressure for safe descent. Pressure and airflow control was obtained by throttling the supercharger intake and varying the size of the cabin discharge opening. Automatic controls have been tried but have not been made to function properly as yet. Fig. 2 shows a typical time altitude diagram for a flight made under pressure conditions. The maximum airplane altitude on this flight was slightly above 30,000 ft. while the cabin pressure was about 11,000 ft. Numerous similar flights have been made with the cabin pressure held at 7000 to 10,000 ft.

Due to the fact that the cabin superchargers are exhaust turbo driven it was necessary to descend using 50 to 60 percent power in order to keep up air circulation. This is undesirable and would not be the case if the superchargers were geared directly to the engines which are equipped with constant speed propellers.

Humidity and Icing

On every flight it has been noted that the relative humidity in the cabin was very low, seldom being above 15 percent and more often below 10 percent at altitudes of 20,000 ft. and above. This condition although not harmful might not be comfortable on flights of several hours duration. It may be found desirable to humidify the air after compression.

Even with the low humidity of the cabin air, considerable difficulty has been encountered with frost forming on the windows of the pilot's and passenger compartments. The first attempt to overcome this difficulty was to pass all the incoming air over the windows but this was not very successful. Putting additional heat in the air did not help materially and the most successful means tried so far has been the use of small auto windshield fans. Each fan would keep a portion of the glass clear.

Taking ice off the outside of the windows is a problem that has not been solved satisfactorily. On the XC-35 airplane it was found necessary to make one of the windshield panels removable and scrape the ice off. This, of course, is impossible with the cabin under pressure and it is necessary to descend to an altitude where the pressure can be equalized. The windshield panels in the XC-35 airplane are of three-quarter inch laminated glass in order to stand the pressure and this makes it impossible to apply enough heat on the inside to melt ice on the outside.

Instruments

Several times during flight tests there has been trouble with the malfunctioning of flight instruments such as the airspeed meter and rate-of-climb indicator, and also other instruments affected by pressure. Instrument case leakage was the cause of the trouble and it will be necessary to improve the instrument cases so that they will operate satisfactorily with cabin pressures up to approximately ten pounds per square inch.

Hydraulic Mechanisms

Another difficulty which presented itself during the testing of the XC-35 airplane at high altitude was the sluggishness in operation of certain hydraulic mechanisms which operated on engine oil pressure. Propellers and supercharger governors were particularly affected by the cold temperature. Where the flow of oil is intermittent or slow, it freezes. It may be necessary to provide a continuous flow of hot oil or heat the lines and parts affected.

Emergency Oxygen Supply

The XC-35 airplane is equipped with an emergency oxygen supply which automatically floods the cabin with oxygen in event the cabin pressure goes below a safe minimum through the cabin rupture, or in case of supercharger failure. To date this emergency oxygen has not been used but is a safety feature which should be retained for some time or at least until the absolute limits of the whole airplane design are determined.

Conclusions

As a whole, the outcome of the XC-35 supercharged cabin project has been satisfactory and has proven, at least to the satisfaction of the Air Corps, the feasibility of supercharged cabin operation. Numerous technical difficulties were anticipated and, as pointed out above, several were encountered, but none of them

should be insurmountable and it is merely a matter of time and normal development before entirely satisfactory installations are in operation.

Summarizing the main problems and lines along which development should take place before pressure cabin operation is entirely satisfactory, they are:

(1) Improvement in intercoolers and turbo-supercharger accessories for operation above 20,000 ft.

(2) Development of mechanically driven cabin superchargers.

(3) Improvement of fuel systems.

(4) Development of practical fuels with lower boiling point and vapor pressure.

(5) Development of automatic cabin pressure and airflow controls.

(6) Improvement of air system for running flight instruments and de-icers.

(7) Development of satisfactory means for preventing or eliminating ice on windows.

(8) Improvement of instrument cases to stand cabin pressure.

(9) Improvement of hydraulic systems so that they will operate satisfactorily under very cold temperatures.

(10) Continued improvement in structural and mechanical details.

Book Reviews

Interpretive History of Flight, by M. J. B. DAVY; The Science Museum, South Kensington, London, 1938; 205 pages, ill., 5s, postage extra.

While aeronautics spreads its roots in legend, literature, and early scientific speculation and covers a period of practical development of a century and a half, it is still too early to expect a definitive history of either the art or the science. The balloon phase is the nearest to the point where conclusive opinions may be expressed. The airship is still in a controversial period.

The importance of the part gliders have taken in the evolution of the airplane is seldom stressed with sufficient understanding. This division of aeronautics has not yet reached a point where one could write with any degree of certainty of its ultimate place in aviation. Mechanical flight is too recent a development to be evaluated by the writer of aeronautical history.

The author has avoided a factual account of flights. He gives in the early chapters an interpretation of the progressive accumulation of knowledge which preceded the work of the Wright brothers. He makes this clear in the following paragraph.

"It will be evident from the foregoing that the aeroplane was not first conceived, built and flown by one or even two men, but was evolved gradually over a period of about 100 years by several men of science, engineers and practical experimenters, each of whom contributed in some small measure to the accumulation of knowledge and experience which made mechanical flight possible. Nevertheless the aeroplane was invented (in the sense of successfully devised) by the Wright brothers, because they were the first to apply the existing knowledge in a manner which was favourable to success, to acquire further knowledge and to contrive a system of control which was effective. They were also the first to apply a suitable engine to a proved machine, and above all they were the first to accomplish free flight."

After an excellent account of the accomplishments of the Wright brothers the book summarizes the contributions made by experimenters during the first decade of the century, leading naturally into the war period. The concluding chapters are devoted to the modern phase of air transport and the social and economic aspects of flight.

The author states that it was not until 1926 that the original Wright airplane was renovated for exhibition purposes. This is incorrect as this machine was reassembled in 1916 and exhibited publicly for the first time at the dedication of the Massachusetts Institute of Technology at Cambridge. The great public interest in efforts to have this first Wright airplane brought back to this country is a contrast to the apathy which permitted this great American relic to remain in boxes for thirteen years without any museum or other public body securing it so that it could be seen by the public.

Mr. Davy will have many successors in attempts to give proper credit to the pioneers in the evolution of flight. If they are all as discerning and impartial, aeronautical history will in a few years gradually omit from its pages many controversies of the past.

LESTER D. GARDNER

Complete Model Aircraft Manual, by EDWIN T. HAMILTON; Dodd, Mead & Company, New York, 1938; 569 pages, ill. $3.50.

The revised edition of this standard work on models is virtually a new book. In its 569 pages it gives to those who are interested in the construction and operation of model aircraft an encyclopedic exposition of all phases of this junior branch of aeronautics. It is a book of instruction that treats of the use of tools and materials in the building of models of many types. Sixty-five models, including gliders, stick models, solid scale models, and flying scale models are presented with specifications of materials and designed plans. The diagrams are simple and so clear that any boy with a mechanical interest can make elaborate flying models. The book is well illustrated by drawings and photographs of every possible part of a model.

Aircraft insignia of commercial and military aircraft are shown and an aviation dictionary is included.

The author is an experienced aviator who has spent five years of research in every phase of model aircraft building and flying. His new book will be welcomed by the thousands of enthusiastic constructors of small model aircraft, many of whom have shown great ingenuity in their design and construction.

Structural and Mechanical Problems Involved in Pressure (Supercharged) Cabin Design

JOHN E. YOUNGER, *University of California*

Presented at the High Altitude Flight Session, Sixth Annual Meeting, I. Ae. S. January 27, 1938

THIS paper is a summary of the principal features of the laboratory investigations carried out at Wright Field during 1935 and 1936, on pressure cabins, the results of which formed the basis of the specifications of the first practical sub-stratosphere airplane, the Air Corps Model (Lockheed) XC-35.[1] While these investigations have sufficient historical interest to make their presentation worth while, their principal value, however, lies in the fact that they were of a fundamental nature, and regardless of the perfection of the art, the principal results will still be applicable to the design of pressure cabin airplanes.

A preliminary investigation of the general problem of supercharging an airplane cabin showed that at least one satisfactory solution must be found for each of twenty-five sub-problems. The degree of success of any pressure cabin airplane will be determined by the sum of the satisfactory solutions of these twenty-five design problems. The Wright Field investigations were successful in that at least one practical answer was obtained for each of the sub-problems. Future developments will be in the refinements of these solutions. The specific problems are:

A. Structural Features

(1) Shape, type, and size of structure: Design factors.
(2) Making the joints air-tight.
(3) Expansion of the skin under pressure.
(4) Temperature stresses combined with pressure and flying stresses.
(5) Problem of explosion, in case of failure of joints or development of cracks.
(6) Development of bulkheads.
(7) Design of glass windows.
(8) Visibility of pilot.

B. Mechanical Features

(9) Doors, emergency exits, etc.
(10) Glands for control wires, tubes, etc., to control surfaces and engines.
(11) Control of fogging and frosting of windows and frosting of interior of cabin.
(12) Automatic window flaps to hold air pressure in case of breakage of windows.
(13) Utilization of dynamic air pressure and energy of air discharged from the cabin.
(14) Effect of supercharging on instruments.

C. Air-Flow and Regulation

(15) Air compression (supercharging) equipment.
(16) Automatic and sensitive regulation of quantity and pressure, free from noise and danger of freezing at altitudes.
(17) Automatic sealing of cabin and release of oxygen spray in case of failure of superchargers or other parts.
(18) Safety valves, inward and outward.

D. Physiological

(19) Air requirements.
(20) Pressure requirements.
(21) Rates of compression or discharge of air permissible in an emergency.
(22) Design of emergency oxygen equipment.
(23) Temperature control.
(24) Humidity control.
(25) Ventilation (air circulation).

Experimental and Analytical Investigations

Space does not permit a detailed description of the hundreds of experiments and analytical investigations required to find a satisfactory answer to all the twenty-five problems. The project was given priority and the project engineer had the ablest assistance available for each problem. As a final proof investigation, a complete supercharged cabin unit was installed in the refrigerated room of the Power Plant Branch at Wright Field and connections made to simulate, as nearly as possible, the conditions of sub-stratosphere flying. From the results of all these investigations, the specifications for the XC-35 were written.

Discussions of the Problems of Pressure Cabin Design

As a basis for discussions and future developments, it appears advisable to present the conclusions arrived at in the Wright Field laboratory investigations of the pressure cabin design problems. These conclusions and

[1] Air Corps Technical Report No. 4220 by the author as project engineer, and eight collaborators; 250 pages.

their discussions are, in general, transcribed from Air Corps Technical Report 4220 and the specifications of the XC-35.

A. *Structural Problems*

(1) *Shape, type, and size of structure; design factors.* The simplest and lightest type of structure is a pressure vessel of the round cylindrical type with hemispherical heads. The stresses in the structure of such a vessel are all tensile except for certain bending stresses at the junction of the cylindrical elements and hemispherical heads. These are generally referred to as "discontinuity stresses."

The present standard design of semi-monocoque construction of fuselages is quite suitable for pressure cabin construction. If the fuselage has fairly rigid annular bulkheads, the discontinuity stresses will also be introduced at the junction of the skin and the bulkheads.

It is gratifying to note that, in general, the design stresses in a pressure vessel may be more accurately calculated than can the usual flying and landing stresses in an airplane.

Design factors. In arriving at a design factor, consideration must be given to the following conditions:

(a) Expansions and contractions of the structure due to cabin pressure and outer temperature.

(b) Normal flight and landing conditions with the cabin unsupercharged.

(c) Normal flight conditions with the cabin supercharged to the basic design pressure.

(d) Design of the cabin as a pressure vessel without consideration of flight conditions.

In a properly designed pressure cabin, there appears to be no probability of the pressure rising appreciably above the basic *design pressure*, hence expansions of the structure may be calculated on that basis; and the factor in the design of the cabin as a pressure vessel may be based solely on the inaccuracies in design and variations in the materials used. And, since, as will be pointed out later, an explosion is improbable and will be of small consequence if it should occur, the factor for the design as a pressure vessel may be quite low, of the order, probably, of 1.5.

In regard to the size of the pressure chamber; from the standpoints of pressure fluctuations, and volume of air available for breathing in case the superchargers fail, the larger the cabin, the better. Where practical, it is desirable to supercharge the entire fuselage.

At the present stage of development, it appears that the cabin should be as nearly hermetically sealed as is possible to make it, with provisions for automatically closing off all discharge outlets in case of failure of the air supply. The air in the cabin will then be sufficient for the time necessary to descend to a lower altitude.

(2) *Making joints airtight.* Experiments performed in connection with these investigations showed that the problem of hermetically sealing the joints of the airplane structure is, in general, fairly simple. At the present stage of development it appears that the type of joint now used in flying-boat hulls, namely a joint in which a strip of fabric, soaked in marine glue or other airproof compound, is placed between the two edges of the metal sheets, is quite adequate. The riveting pitch, as in the case of boat hulls, must of necessity, be small. If it appears necessary, the riveting may be divided into two classes; (1) rows of the larger rivets to give strength to the joints and, (2) rows of the smaller rivets, closely spaced, to seal the joint.

(3) *Expansion of the skin under pressure.* The problem of expansion of the fuselage skin under pressure is not a serious one and in most cases may be neglected. It should be noted, however, that all such expansion problems are subject, with great accuracy, to solution by the ordinary theory of elasticity, since the stresses for such calculations will not, in general, be above the proportional limit of the material. There seems to be no reason, therefore, for not carrying out a complete and accurate stress analysis of all elasticity problems connected with the expansion of the structure. As has been previously pointed out, the calculations for the elastic distortion of the structure should be based upon the basic pressure; that is, upon a design factor of *unity*.

Sliding joints should not be used as a means for providing for expansion. Allowance should be made in the *flexibility* of the structure to take care of expansions or contractions.

(4) *Temperature stresses combined with pressure and flying stresses.* Temperature stresses can, in general, be calculated with a fair degree of accuracy. In connection with the pressure cabin, the contractions due to a low temperature has a tendency to offset the expansions due to the pressure. It should be pointed out, however, that this does not affect the pressure stresses.

The reduction in strength of metals (particularly the fatigue strength) at low temperatures should be taken into consideration in design.

(5) *Problem of explosion in case of failure of joints or development of cracks.* An explosion occurs when the stresses are near the ultimate strength, so that when the structure is slightly weakened the stresses in the adjacent structure immediately become higher than the ultimate strength of the material.

This problem should give no great concern for the following reasons:

(1) An explosion is improbable because,

(a) The design stresses will not be over two-thirds the ultimate for a minimum factor of 1.5.

(b) Safety valves, maximum capacity of superchargers, and manual operation will limit the pressure to the design value.

(2) An explosion of a vessel of thin sheet metal on a relatively heavy frame of bulkheads, stringers, etc.,

will be localized, and will certainly not appreciably affect the flying strength characteristics of the structure.

(3) Experiments have shown that a sudden release of pressure will not, in general, harm the personnel. Hundreds of these experiments were performed with (a) many subjects, (b) various cabin pressures and external pressures, (c) rates of discharge varying from several minutes to about 1/4 second (explosion with loud report).

(6) *Development of bulkheads.* The hemispherical shell is, of course, the ideal type of bulkhead. This type of structure, however, offers the objection of being difficult to form. The hemispherical shell would also occupy valuable space in certain cases. The ideal type of bulkhead where space is important, from a structural standpoint, is the cone. This type of bulkhead may be made quite light even when the ratio of its altitude to its diameter is small. Flat surfaces quickly run into great weight.

(7) *Design of glass windows.* There seems to be, at least, a popular conception that windows for a pressure cabin should be round. There does not appear, however, to be any obvious reason why round windows should be used, and they certainly would not be as easily installed and as convenient as rectangular windows. It appears that narrow rectangular windows, arranged longitudinally with respect to the axis of the pressure cabin, in narrow strips, are most desirable from a structural and a practical standpoint. An extensive program of research was carried out to obtain data on the strength of safety glass, and other special types of glass and compositions used for glass. On account of space the data cannot be given here.

(8) *Visibility of the pilot.* The hemispherical nose on the supercharged fuselage will be the pilots cockpit of the future. The problem of visibility for this type of construction is thrown into the hands of the designing engineer. (Note: The specifications of the XC-35 called for a standard shaped cockpit because it was thought best not to complicate the pressure cabin problem by radically changing the design of the pilots compartment. It was expected, of course, that this would increase the weight. Since, however, the airplane was to be used solely for experimental purposes, weight reduction was not a major problem.)

B. *Mechanical Features*

(9) *Doors, emergency exits, etc.* In designing a door for a pressure cabin the following features should be borne in mind:

(a) The door should be light, and easily opened and closed.

(b) It should not be readily possible to open the door when the cabin is subjected to a differential pressure.

(c) The operating mechanism should be such as would be normally expected in the operation of a door, yet provide for a quick release of the cabin pressure, and thence a normal opening of the door.

The question of whether a door should open inward or outward must be considered. A door opening outward requires fairly intricate operating mechanisms. In the case of a crash a small distortion of the structure may cause the mechanism to bind, thereby preventing the door from being opened. On the other hand, a door which opens inward would require no mechanism for its operation, and need only be held loosely in place against a soft rubber gasket by small spring clips. The reader is referred to the description of the XC-35 for details of door and emergency exit designs.

If doors, emergency exits, and windows open inward, the air sealing problem is extremely simple, since a gasket of about 1/4 inch thick soft air-tight rubber around the door or window is all that is necessary for sealing.

(10) *Glands for control wires, etc.* The principal problem is obviously that of hermetically sealing the exits of the control wires, tubes, etc. Two types of motion are involved, rotation and translation (sliding). The sealing of a gland for a torsion shaft is fairly simple. In the case of translation, the bellows type of gland was considered, but was discarded on account of its bulk and the danger of cracking and releasing the air.

A satisfactory gland should have the following characteristics:

(a) Simplicity.
(b) Requiring a minimum of maintenance.
(c) No possibility of an air leak developing suddenly.
(d) Minimum resistance (friction) to operation.
(e) Absolutely free from danger of freezing.

A small oil sealed gland, insulated from the outside temperature, resulted from these investigations. The sliding element was a small brass tube soldered over the control wire.

(11) *Control of fogging and frosting.* The basic principle involved in the control of fogging and frosting of the windows is to keep the window glass warm enough to melt the ice or frost. This may be accomplished in a number of ways. The air from the superchargers may be directed over the inside surface of the glass, or it may be passed between the two glasses of a double window. It is obvious that other sources of heat may be used; for example, the air from the cabin may be picked up by a small blower, heated, and directed against the glass. Mechanical means of scraping the ice from the glass did not prove successful at very low temperatures.

During the experimental investigations carried out on the complete, supercharged cabin set up in the refrigerated room (at low temperatures, −30°F. to −45°F.), the metal surfaces quickly become excessively frosted on the inside of the cabin. In a period of 4 or 5 hours this frost,

in some cases, attained a thickness of about a quarter of an inch. It was noted, however, that where the felt insulation, which was used, was pressed firmly against the cabin wall there was no tendency to form frost. These experiments led to the conclusion that the insulation of the cabin should be glued to the outer skin with a glue which will not deteriorate or crack at very low temperatures.

Accessories connected to the cabin wall, such as safety valves, control wire glands, discharge valves, etc., should be placed well inside the cabin and insulated from the outside as much as possible to prevent frosting.

(12) *Automatic window flaps.* Early experiments showed that a flap of sheet metal, allowed to drop over the window when the breakage of the glass tripped a supporting trigger, would satisfactorily seal the window with a loss of about 25 percent of the pressure. It was later concluded, however, that at least for commercial airplanes this feature was not necessary.

(13) *Utilization of the dynamic air pressure and energy of air discharged from the cabin.* Neither one of these ideas appears to be practical, at least at the present stage of the project. The dynamic air pressure, even at a speed of 300 m.p.h., is only a small percentage of the cabin differential pressure required, hence cannot be used to effectively assist in building up the cabin pressure.

The kinetic energy of the air being discharged from the cabin is too small to be taken into consideration. The question of using the compressed air in the supercharged cabin for the engines has been considered. The amount of air required for the cabin, however, is quite small (about 10 percent of the amount required for the engines), so that it may not be worth the additional weight of piping and other apparatus to make this practical.

(14) *Effect of supercharging on instruments.* Instruments affected may be housed in a box sealed from the cabin but open to the outside.

C. Air Flow and Regulation

(15) *Air compression (supercharging) equipment.* There seem to be two schools of thought on this subject; one is in favor of a supercharging unit entirely separate from the power plant units. The supercharger of this unit may be operated by a small auxiliary electric motor or a small gasoline motor. The other school is in favor of a supercharger unit operating parallel with the engine supercharger unit. It appears to the author that the latter method will require less weight, and since the units will be as reliable as the motors themselves, it appears that this method is more desirable from the standpoint of reliability.

In any case, two independent sources should be available to guarantee a continuous air supply.

Since the air must be cleaned and conditioned in any case, there appears to be no reason why the air cannot be taken directly from the engine superchargers.

A parallel unit was used on the XC-35.

(16) *Automatic and sensitive regulation of quantity and pressure, free from noise and danger of freezing.* Two types of discharge valves were investigated: (a) a valve operated directly by the barometric pressure, and (b) a valve operated by an electric motor which was controlled by a sylphon bellows pressure element. Other arrangements were proposed, such as balanced valves operated by a sensitive pilot mechanism utilizing an outside source of energy. The direct-operated valve, while not accurate through a wide range of pressures was considered sufficiently satisfactory to use in case nothing better could be developed in the time available. The discharge valve should have sufficient capacity to properly care for the entire maximum discharge of the superchargers without appreciable rise in pressure above the basic design pressure.

Felt insulation on the inside of the air lines and valve chambers was found to effectively deaden the noises of the air streams.

Regulation of the quantity of air flowing into the cabin from the supercharging unit is desirable. This problem is closely associated with the regulation of the pressure and the discharge of air. Eventually the intake, discharge, and pressure, will be regulated by a single automatic unit.

(17) *Automatic sealing of cabin, etc.* The possibility of the failure of the superchargers supplying the air to the pressure cabin should be provided for. Effective check valves should be installed in the line to prevent the reverse flow of air out of the cabin into the supercharger; and in the case of a loss of pressure in the cabin, provisions should be made for automatic spraying of oxygen among the passengers from emergency tanks provided for the purpose.

(18) *Safety valves.* It was found that for low pressures as would be found in a pressure cabin, the simple spring loaded valve of light construction showed no tendency to flutter, and in general, seemed to be satisfactory. It was found that these valves placed directly on the skin of the fuselage would frost over at low temperatures, and would not operate. They must therefore be placed well inside the cabin, and connected with the outside by a tube. Two such valves were recommended for the experimental ship.

Since an inward pressure, on a monocoque fuselage, of only a few ounces per square inch would cause the walls to cave inward, a valve to prevent this condition must be provided for. In the experimental work a flap of sponge rubber was hung on the inside of the cabin, like a curtain, over several small holes in the cabin skin. Pressure on the inside would keep the flap pressed over the holes. A release of this pressure would allow the flap to hang clear of the holes thereby equalizing the internal and external pressures.

D. Physiological

(39) *Air required per passenger.* This has not been definitely settled, but it appears that 10 to 20 cu. ft. per min. per passenger at sea level pressure is desirable. It may be possible that the personnel requirements of air will not be the criterion for the supercharger capacity. If the pressure cabin is to be heated through the medium of the intake air, it may be desirable to increase the quantity of air rather than heat the air to a high temperature in order to obtain the number of heat units for cabin heating. These are problems, however, which will have to be worked out thoroughly in actual flight conditions.

(20) *Pressure required.* An ideal condition for passenger cabins would be sea level pressure at all altitudes. This would require about 10 lbs. per sq. in. differential pressure for altitudes of 25,000 to 30,000 ft. However, many are of the opinion that a 10,000 ft. to 12,000 ft., condition at 25,000 ft. is sufficient. In this case a pressure of less than 5 lbs. per sq.in. is required. Service operation will probably have to determine this question.

(21) *Rate of discharge permissible.* As previously pointed out these investigations showed that an explosion, in general, is not detrimental to personnel on the inside.

(22), (23), (24), *and* (25). These are all design problems which require experimental flight data for an exact solution.

Books Received

The New Cadet System of Ground School Training, by LT. LESLIE THORPE, 1935. Vol. 1, **Aerodynamics and Theory of Flight**; 122 pages, ill., $3.00. Vol. 2, **Materials, Construction, Rigging, Maintenance and Inspection;** 208 pages, ill., $3.00. Vol. 3, **Engines, Ignition, Carburation, Diesel Engine Supplement;** 234 pages, ill., $3.00. Vol. 4, **Navigation, Meteorology, Radio Beam Flying and Orientation Procedure;** 172 pages, ill., $3.00.

Aircraft Manual, by JACK LINKE; 1935; 289 pages, ill., $3.50. **Metal Aircraft,** by WILLIS L. NYE; 1935; 227 pages, ill., $3.00. **Simplified Definitions and Nomenclature for Aeronautics,** by LT. LESLIE THORPE; 1931; 128 pages, $1.50. **Aviation Service and Maintenance,** by JAMES G. THOMPSON; 1937; 161 pages, ill., $3.00. **Modern Aircraft Radio,** by WILLIS L. NYE; 1937; 346 pages, ill., $4.00

Published by the Aviation Press, 580 Market Street, San Francisco, California.

The publishers of The New Cadet System of Ground School Training and other books for students have sent a complete set of their publications for the library of the Institute. All of these books have been published within the last three years and comprise what may be termed a one foot library shelf for pilots and mechanics. Written in simple style, the set is obviously intended for aviation school students and others who have not studied higher mathematics. In the volume on aerodynamics the author has simplified the presentation so that the rudiments may be grasped by the average high school student. In the volume on materials, construction and maintenance the examination question method has been employed to reinforce the student's grasp of this subject. A glossary at the end of each of the four volumes further adds to the student's information.

The third volume of the series deals with engines, and the last of the series gives in condensed form the elements of navigation, meteorology, and beam flying.

The aircraft manual gives the mechanic a practical book of instruction on the inspection, maintenance, and repair of aircraft. It will serve as a quick guide for the sportsman pilot, a text for the ground school student, and a reference book for the shop foreman.

The wider use of metal construction in aircraft necessitates a more specialized knowledge of the uses in design and construction of various metals. The volume on metal aircraft acquaints the shop worker with the details of various parts of aircraft and the tools required for their fabrication and repair.

A most useful booklet in the series gives the nomenclature of aeronautics which will be handy as a reference book for anyone who wishes a simple and accurate definition of the leading aeronautical terms.

Last year two new volumes were added to the series, one on aviation service and maintenance and the other on aircraft radio. The former is intended to be a reference manual for the commercial operator, light plane owner, and student mechanic. The book, after general introductory chapters, gives in a condensed form the technical information needed for service operation on the leading types of engines and commercial aircraft.

Radio has become such an essential part of all airplane operations that a special volume is required to cover its ever widening field. Here again the author has simplified a highly technical branch of electrical engineering.

The complete set gives the student easily understood text books which are adapted for class room instruction and subsequent reference.

The Trend Toward Higher Altitudes in Commercial Air Transport

W. B. KLEMPERER, *Douglas Aircraft Company*

Presented at the Air Transport Session, Sixth Annual Meeting, I. Ae. S.
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Introduction

THERE are three obvious reasons for seeking higher altitudes in commercial air transport flights. The foremost is to escape unfavorable weather regions. The second is to increase the safety of instrument flying by raising the clearance margin over a wide range on either side of the radio range course. The third reason is the potential increase of performance due to higher speed or fuel economy attainable in thinner air.

Weather Problems

As far as safe margins above the terrain surrounding the Air Lines' routes on the North American Continent are concerned, there would hardly seem to be a great incentive to go much above 15,000 ft. while most of the trips across the continent would be at levels below 10,000 ft. Unpleasant weather phenomena are known to extend to the 25,000 ft. level but there is reason to believe that a service ceiling of the order of 20,000 ft. would permit many a storm to be jumped. More information about conditions above the clouds of the troposphere in bad weather is eagerly awaited from the "radio-meteorographoligists." As to the improvements of performance with altitude, it is a somewhat elusive quantity. Higher airspeeds are possible aloft but the additional weight necessitated by high altitude equipment encroaches upon the gain for a given range. If the airspeed and gross weight are not increased with the higher altitude, then there is a definite distance for which the saving of fuel balances the weight of the extra altitude equipment. From a flight schedule standpoint, however, the picture of high altitude performance is greatly influenced by the winds aloft. Here again meteorological research under all sorts of weather conditions will eventually furnish statistical data on which probable altitude advantage calculations can be based for any definite route and season.

Physiological Comfort at Altitude

As far as physiological comfort at altitude is concerned, much can be accomplished by maintaining sufficient oxygen partial pressure in the breathing air to ensure normal saturation of arterial blood. While many individuals can occasionally or by acclimatization tolerate altitudes of the order of 18,000 ft., yet it has been amply demonstrated that a physiological benefit is derived from an oxygen admixture sufficient to boost the oxygen partial pressure of the inhaled air to the equivalent of a lower level such as 8000 or 10,000 ft. It is therefore undoubtedly worth while to provide oxygen equipment for present day transport planes in order to make occasional use of their high ceilings.

In past high altitude routine flights oxygen was usually breathed by mouth through a smoker's mouth tube. This method is indeed simple but it has obvious drawbacks. It requires a conscious effort in an unnatural breathing technique of inhaling partly through the tube and partly past it. The dry and cool oxygen impinges on the delicate membranes in the mouth. During exhalation the uninterrupted oxygen flow is wasted. An investigation of what can be done with simple means to improve both comfort and efficiency led to a convenient technique for testing various methods of breathing oxygen-enriched air. Oxygen conservation can be improved almost 100 percent over the mouth tube and an agreeable amount of humidity can be rebreathed without excessive accumulation of CO_2 by inhaling the oxygen flow naturally by nose through a small cup attached or held to the face. These cups can be designed to be light, transparent, reasonably inconspicuous, inexpensive, readily removable and unobstructive to vision and speech or to the use of a microphone. Such devices are now on practical flight tests. Some were specially designed for pilots' use, fastened to the cap or worn with temple holders or head bands; others were designed for passengers' convenience and it is believed that not only will they not be objectionable to the traveler but eventually demanded by those who have become acquainted with the benefit derived from them. For sleeper passengers a convenient and comfortable transparent curtain serves to retain sufficiently "conditioned air" for moderate requirements.

Other experiments have been directed toward more drastic conservation of oxygen for special purposes. For instance, breath control of oxygen flow to a nose catheter by means of a valve actuated by the chest expansion of the wearer was tried out. Obviously a complete rebreathing circuit which catches the exhaled air and retains it in a breather bag and purifies it would serve still better oxygen economy. The amount of oxygen needed conjures up a serious weight problem

as soon as many people are to be served during extended periods unless complete rebreathing is accepted. The oxygen supply can be carried on board in compressed, liquid, or chemical form. Proper distribution of flow to many tap stations on board requires a slight over-pressure in the manifold line, best to be automatically regulated by an aneroid control with fixed orifices at each tap.

The question has been raised, to what extent an oxygen system constitutes an extra fire hazard. Of course, the lines must be so laid that leaks cannot impinge upon inflammable material where ignition sources can be present. Smoking tobacco is of course not compatible with inhaling oxygen. However, it must be noted that at 16,000 ft. the oxygen concentration in the inhaled air need not be larger than 28 percent (instead of the normal 21 percent) in order to condition the air to be equivalent to the 10,000 ft. level and the oxygen partial pressure is lower than in natural sea level air. Therefore a cigarette does not flare up in air conditioned to be equivalent to, say 6000 ft. or 8000 ft. below flight level.

All possible disadvantages of individual inhalers would be eliminated by enriching the whole cabin with enough oxygen to condition it to some lower altitude. A few percent of additional oxygen would already go a long way. The automatic regulation of proper oxygen concentration offers a very interesting problem. However, it would be impracticable to carry enough oxygen for the conventional number of air changes per hour. If the cabin could be sealed and recirculation and deodorization equipment installed and ventilation reduced to but a few changes per hour, the weight could be brought down to where it would not necessarily be prohibitive, although still high.

If, however, the same weight is put into a pressure cabin many other advantages can be achieved. In a pressure cabin the air is kept at a higher pressure than prevails outside at high altitude. The passengers are saved the disagreeable effects of rapid pressure changes in a fast descent. With a pressure cabin the flight schedule need not be stretched for physiological reasons. The pressure cabin therefore appears to be the most desirable solution of the high altitude flight air conditioning problem.

Design Considerations

The question just for what pressure to design the cabin, is governed by considerations of weight, cost, and simplicity. Obviously it is not necessary to maintain sea level pressure in the cabin. For instance, with a pressure differential limit of $2^1/_2$ lbs. per sq.in. the cabin air can be held at 9000 ft. pressure while flying at 16,000 ft., whereas it would take 5 lbs. per sq. in. at 25,000 ft. The extra weight of a pressure cabin is made up of several components. The component due to sealing the cabin depends somewhat on the design and size of the ship and on the arrangements of power plants. Another component is due to the reinforcement of various structural elements; this component increases more than in proportion to the pressure differential. A third component is that due to the apparatus for supercharging and air conditioning of the cabin. It depends on the pressure ratio and on the type of power available for the cabin supercharger and heating which incidentally also influences the choice between ample fresh air supply or recirculation and deodorization. There is no difficulty of supplying enough oxygen or of getting rid of excess CO_2, and the maintenance of agreeable humidity favors a well-balanced system of partial recirculation requiring neither addition nor removal of moisture from the cabin air.

The question of the cabin supercharger drive and power supply is somewhat linked up with whether or not and how the engines are supercharged. To branch cabin fresh air from supercharged engine air looks attractive on first thought but it involves difficulties with multiple engine installations and requires precautions against aspirating oil and alcohol vapors into the cabin air. Undoubtedly the cleanest air is caught in the nose of a transport airplane having wing engines. Electrical drive of cabin superchargers appears natural to the electrical engineer. However, electrical power aboard is usually at a premium. Separate power plants involving separate fuel and exhaust systems are hardly justified for cabin superchargers. Drive by main engine power requires means permitting regulation of the cabin blowers independently of the engine speeds.

Structural Problems

Among the foremost structural problems is that of the cockpit. To strengthen a conventional cockpit enclosure is merely a matter of weight put into the skeleton of the shell, to keep oval frames from becoming round under pressure and to take care of stress concentrations around windows, escape hatches and access holes. A structurally more efficient pilots' compartment is often visualized as occupying the nose of a streamlined body of revolution. While this would be aerodynamically attractive it requires large window areas to give good visibility. A study of the compromise offered by a fuselage whose shape comprised the intersection of two bodies of revolution led to forms which showed up quite favorably from a drag standpoint in wind-tunnel tests, in addition to providing room for devices that have to stay outside of the pressure shell about the nose of the fuselage.

In fact the problem of segregating the various airplane parts inside and outside the pressure shell without too many cut-outs, recesses, and bulges, tends to be much more involved than that of making the fuselage skin carry the pressure in tension and than sealing the seams and glands. Tests made on a fuselage segment have served to determine how secondary skin stresses

and flush riveting may affect the requirements for skin attachment to frames and stringers in order to keep deformations in bounds and avoid fatigue from pressure cycles.

Explorations into stress concentration on metal skin prompted the development of several new strain gages which may be of interest for other purposes as well. One has a .2 in. gage length. Another was designed to measure the 3 strain-tensor components in a 1 in. triangle simultaneously and thus give an immediate clue to not only the two principal stresses but also to the orientation of their axes in the sheet in the presence of membrane shear. These gages are relatively inexpensive and put on by means of a suction cup. They served to gain interesting detail data on the stress flow in composite structures subjected to pressure.

Conclusions

The structural problems of pressure cabins are readily reduced to well known principles so that they can be treated either theoretically or experimentally and they do not seem to obstruct the attainment of higher flight altitudes in air transport. It seems that the immediate future of commercial higher-altitude flying will be a step-by-step development: first, oxygen for the crew to ensure their mental alertness and protect them from insidious and accumulative effects of oxygen privation; second, "low-level air conditioning" oxygen service to passengers; third, pressure cabin supercharged to fractional pressure differential, without fully supercharging the engines; fourth, pressure cabin with supercharged engines. A gradual increase of ceiling would naturally accompany this development.

Book Review

L'Alimentation en Combustile des Moteurs d'Aeronautique, by Basile Demtchenko; Gauthier-Villars, Paris, 1937; 239 pages, ill., 90 francs.

"When theory and practice disagree it means that not all the factors of theory were taken into consideration." This statement is especially applicable to the analysis and actual performance of the fuel system of a modern airplane.

Three factors affect proper supply of gasoline to the engine: resistance of the lines and accessories, change of pressure and temperature with altitude and acceleration due to change in attitude of the airplane. In order to make an intelligent analysis of the fuel system it is necessary to use a method similar to bookkeeping, entering the factors conducive to the flow such as gravity head and pump pressure on the credit side and the factors detrimental to the flow on the debit side.

The book is divided into two parts: technological and theoretical. In the former the author covers the general technique of the fuel system installation, gives practical rules and describes the accessories used in current French practice. Numerous schematic diagrams of the typical cases ranging from simple single engine units to complicated four engine installations are presented and discussed. The theoretical part of the book is of more interest to the American reader due to its universal application. Gasoline vapor tension, volatility, dissolved air, atmospheric pressure, temperature, and other factors, often causing formation of vapor lock, are treated to the extent of present knowledge on the subject.

In cases such as the hydraulic resistance of various accessories, where rational approach is impossible, experimental results are given in the form of graphs. Acceleration, which is a critical factor for military airplanes, receives considerable attention and equations are derived for diving, climbing, turning, and banking.

The most interesting chapter in the book is the last one where a form chart is developed in which all the factors effecting performance of the system are entered, computed, and summarized giving the final conclusion with respect to the efficiency of installation and possible ways to improve it. Several examples are worked out in detail.

In conclusion I may say that this book is written for a specialist concerned with the function and ailments of the heart of an airplane. When confronted, for instance, with an apparently innocent problem of air bubbles in the fuel lines causing low ceiling one must prepare for a more or less extensive trip into the realm of physics. This book may save such a trip and offer the designer a practical solution of the problem.

A. N. Petroff

Physiologic Considerations Governing High Altitude Flight

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Introduction

IN THE rapid advance in aviation much attention has been devoted to the construction of aircraft designed to withstand the powerful forces encountered when operating at high speeds and at great altitudes while, until recently, too little thought has been given to the deleterious effect of these factors upon the pilots and passengers.

It is now generally realized that before going further with design and construction, the industry must ascertain from the physiologist whether the operating conditions planned are favorable for the comfort and well being of the human organism. Otherwise aircraft will be operated inefficiently and passengers discouraged from using this method of travel.

It is true that more and more thought is being devoted to passenger comfort and that modern aircraft construction and operation have done much to protect the air traveller from the harmful effects of cold, wind, vibration, acceleration, and noise. Nevertheless the problem of combating the injurious effects of high altitudes still remains very much in the foreground and stands as a challenge to those striving for high altitude flying.

Oxygen Want

As one ascends higher and higher into the upper atmosphere, certain disturbances of bodily function become apparent. If we examine the physical properties of the atmosphere at various altitudes, it will be found that the relative percentages of the gaseous constituents of the air remain the same as at sea level. That is, there is approximately 21 percent of oxygen and 79 percent of nitrogen at all altitudes. The barometric pressure of the air and the partial pressures of its components continuously decrease, however, with increase in altitude. Many of the symptoms occurring at high altitudes were known long before the composition and pressure of the atmosphere were understood and were commonly attributed to poisonous emanations. Later increased radiation and ionization of the air at the higher levels were regarded as contributory factors. Real knowledge of the effects of high altitudes was first gained from the classical work of Paul Bert begun in 1878 through which he demonstrated that the symptoms are principally due to the diminished partial pressure of oxygen. Subsequent experiments have amply confirmed Bert's original contention and we must consider it as conclusively proved that the majority of the ill effects of high altitudes or low atmospheric pressures are due to this cause. The reason for this is that oxygen absorption by the lungs depends on the pressure of this gas within them and when this pressure is reduced, the passage of oxygen from the lungs into the blood stream is hindered and the body suffers from lack of oxygen. The medical term for this state of affairs is "anoxemia." This is an extremely serious condition for in higher animals the immediate cause of death is always a lack of oxygen which arises from the circumstance that the body has scarcely any internal storage capacity for oxygen but depends from moment to moment on its supply from the air.

Anoxemia is so far reaching in its consequences that it may impair every phase of the body's activity ranging from the psychologic to the physiologic. The symptoms produced may be of a transient nature with no harmful after effects, but if the oxygen deprivation is too severe or of too long duration, permanent injury may result. Most organs can be deprived of oxygen for a very short time only before they become irreparably damaged. For example, the brain can withstand complete oxygen lack for only seven or eight minutes, after which it permanently ceases to function, while severe anoxemia for shorter intervals usually results in distressing after effects.

The altitudes to which man can ascend with and without the use of oxygen depend, to a certain degree, on the rate and to a very great extent on the individual and upon his physical condition. One must not lose sight of the fact that one must differentiate between the limit of efficient functional capacity and the limit consistent with life. Without the use of oxygen, unconsciousness usually occurs at about 25,000 ft. and if exposure is sufficiently prolonged at this altitude, death will result.

With respect to the altitude attainable when breathing pure oxygen, many think that this height is limitless. That this is not the case may be readily seen from a few simple calculations. As has been previously mentioned, the amount of oxygen available for use by the body depends on its pressure in the lungs. Suppose, therefore, pure oxygen is breathed at 45,000 ft. where the barometric pressure is 110 mm. Hg. Within the

lungs 47 mm. of this pressure will be due to water vapor and 40 mm. to carbon dioxide, an end product of respiration. This leaves only 23 mm. of pressure available for oxygen which would produce asphyxial symptoms at once. At 36,000 ft. an aviator breathing pure oxygen would be in much greater danger if, owing to some accident he took several breaths of the surrounding air, than a miner would if he took several breaths of an atmosphere of fire damp. The miner would have in his lungs to start with a pressure of about 700 mm. of oxygen, whereas the aviator would have only about 90. A popular misconception which exists in the minds of many is that reduced barometric pressure is not responsible for oxygen lack. From the foregoing discussion it will be seen that this idea is decidedly erroneous. One could be placed in an atmosphere of pure oxygen, but if the pressure were not sufficiently high, death by suffocation would occur. When oxygen was discontinued at 30,000 ft., a member of the laboratory staff became unconscious in $1^1/_2$ minutes and it was found that animals would die in 3 to 4 minutes while breathing pure oxygen at an altitude of 50,000 ft.

Mechanical Effects of Altitude on the Body

The low barometric pressures which are encountered at high altitudes are known to exert certain mechanical effects on the body. These decreased pressures cause an expansion of the gases in the stomach such that their gas volume is doubled at 18,000 ft. and tripled at 27,000 ft. This marked expansion of the gastro-intestinal gases may cause an acute dilation of the stomach with consequent crowding of the heart and lungs to the extent that general collapse, fainting, and even death might result. The severity of the symptoms depends to a large extent on the amount and nature of the food ingested and on the intestinal fullness.

Expansion of gases within the sinuses and cavities of the head frequently produces severe headaches at high altitudes when the cavity openings are blocked by inflammation or other causes. A painful example of such a state of affairs occurs when the air pressure in the inner ear fails to equalize with that of the surrounding atmosphere. Pressure equalization in the ear is brought about through the eustachian tube which connects the inner ear with the throat. This tube, which is only a potential tube and normally closed, may be voluntarily opened by swallowing, yawning, or other similar acts. Failure to open the eustachian tubes during changes of altitude in aircraft flights is most frequently due to ignorance of the necessity to do so, but may be due to carelessness, to being asleep, from the influence of analgesics, or anesthetics, or from coma. The first two of these instances usually occur among inexperienced pilots and passengers, the third on sleeper airplanes, and the latter ambulance planes.

Another cause for the headaches is due to the increase in spinal fluid pressure with decrease in barometric pressure. It has been found that the spinal fluid pressure begins to increase at about 15,000 ft. and continues to rise with increase in altitude. Between 15,000 and 18,000 ft. an evolution of bubbles probably consisting principally of nitrogen occurs within the fluid. At a 50,000 ft. altitude pressure, an increase in spinal fluid pressure as high as 400 percent has been observed. This tremendous pressure within the skull may produce damage to the brain or seriously interfere with its functioning.

When a diver, who has been working at great depths under increased air pressures, comes to the surface too quickly, the sudden lowering of pressure permits the rapid evolution of nitrogen from his blood which may be released in the form of minute bubbles. This causes severe joint pains which are commonly known as the "bends." In rapidly ascending to high altitudes, the aviator is in much the same position as the diver, for he is undergoing a rapid reduction in pressure. As far back as 1934 the laboratory personnel reported the occurrence of joint pains on high altitude flights and experience in the low pressure chamber has strengthened suspicions that "bends" actually occur under these conditions.

It is a well known phenomenon that the temperature at which water boils decreases with increase in altitude. The boiling point of water at sea level is 212°F. Our body consists of approximately 80 percent water which is maintained at a temperature of 98.0°F. This temperature is the boiling point of water at 63,000 ft. altitude pressure, so that when this altitude pressure is reached, the body fluids should boil. This phenomenon has actually been seen occurring in the low pressure chamber, an animal boiling due to its own heat. Body fluids begin to vaporize, however, long before the boiling point is reached and are removed from the body principally through the lungs. A loss in weight of 15 pounds after exposure to 40,000 ft. altitude pressure for a half hour has been observed due to this cause.

Selecting a High Altitude Compartment

The symptoms and after effects of ascent into high altitudes have been briefly reviewed. Here, as in other medical problems, it is rather a question of prevention than of cure. The solution is obvious. Increase the partial pressure of oxygen and maintain the barometric pressure at values consistent with health and comfort. From a practical standpoint, the application of this solution, in providing a suitable environment for high altitude air travel, appears to be through the use of sealed aircraft compartments within which artificial conditions may be created and maintained. Although the mechanical details and actual construction of such compartments is an engineering problem, the question of what constitutes a proper physiologic environment is a medical problem.

After a careful analysis of all the possible types of sealed high altitude compartments, it is found that

they can be divided into three distinct classes as follows: *Pressure Compartments* in which an adequate partial pressure of oxygen will be maintained at all levels by forcing outside air through the compartment under pressure. In this case there will be a constant flow of fresh air to replenish the oxygen used. *Oxygen Compartments* in which the consumed oxygen will be replaced from an auxiliary supply carried in the airplane which will keep the oxygen at the desired partial pressure by enriching the contained atmosphere. As has been previously pointed out, anoxemia develops rapidly above 32,000 ft. even when pure oxygen is breathed. Hence this is the critical altitude to which passengers may go in this type of compartment. It should be noted that no free circulation of atmospheric air can be allowed through the compartment due to the resultant dilution and waste of the oxygen supply, but an equalizing valve will be required to allow compartment pressures to vary with the barometric pressure on ascent and descent.

In the third type, the *Oxygen-Pressure Compartment*, the consumed oxygen will be replenished by an auxiliary oxygen supply and the oxygen partial pressure will be maintained by both increased oxygen percentages and increased compartment pressures.

The choice of the most desirable of these three types, from an engineering standpoint, will be governed principally by limitations of weight and cost. The oxygen cabin has the advantage in that almost any modern airplane fuselage may be converted into this type of compartment without radical change in existing designs; while the construction of a pressure resisting cabin entails considerable re-design adding much to the weight and cost of the airplane. On the other hand, from the medical standpoint, the altitude of the oxygen cabin would be limited to about 30,000 ft. while the pressure cabin would function satisfactorily at much higher levels. In addition, the constant barometric pressure within the pressure compartment would permit the rates of climb and descent to be governed by aerodynamic rather than physiologic considerations. From this it appears that the pressure cabin is the type of choice, for by this means a reasonably normal environment with adequate oxygen and free from the harmful effects of change of barometric pressure can be maintained.

Physiologic Requirements of the Pressure Cabin

Having determined the most suitable type of high altitude compartment, it is now possible to proceed with a discussion of the physiologic requirements of the pressure cabin. For convenience in presentation, they have been divided into seven main headings, as follows:

(1) Temperature control
(2) Humidity control
(3) Ventilation
(4) The carbon monoxide problem
(5) The carbon dioxide problem
(6) Barometric pressure consideration
(7) Oxygen requirements.

Recent advances in the science of air conditioning have rather definitely established the optimum comfort levels with respect to temperature, humidity, and ventilation and the requirements of these items for the pressure cabin do not differ essentially for those existing on the ground. With respect to the other members of the above group, peculiar problems arise in connection with their control at high altitude aircraft compartments.

CO and CO_2 Problems

If the compartment is to be maintained at a pressure altitude above sea level, the carbon monoxide problem becomes increasingly serious. Concentrations of carbon monoxide which are innocuous on the ground become dangerous with decrease in barometric pressure and not a trace of this gas should be tolerated in the compartment.

Carbon dioxide is a waste product of body metabolism and will tend to accumulate within the compartment. It exists in the lungs in a concentration of from 4 to 5 per cent and occurs in the normal atmosphere to the extent of 0.03 percent. The presence of this gas in the lungs and blood is vital to breathing for it regulates the rate and depth of the respiratory movements. A reduction of the carbon dioxide concentration in the lungs by only 0.2 percent below the normal produces a suspension of breathing while an increase of 0.3 percent triples the normal vetilation. It is possible therefore to partially counteract the effects of oxygen-want by increasing the percentage of carbon dioxide in the inspired air, the accelerated breathing causing an increase in oxygen pressure in the lungs. Three percent carbon dioxide in the inspired air noticeably increased breathing while 10 percent causes fainting, distress, and fatigue. More than 10 percent causes stupefaction, acts as a narcotic, and quiets respiration.

From the foregoing it is obvious that the carbon dioxide concentration in pressure compartments must be under careful control. Not only must the excess be eliminated, but according to the pressure carried must be capable of regulation within certain limits. At compartment pressures of from 760 to 660 mm., the carbon dioxide may be eliminated completely or kept at any low level. To prevent unnecessary increased lung ventilation and allow for a safety factor of one, a concentration of 0.5 percent or below is required. At compartment pressures below 660 mm., the body may begin to suffer from oxygen-want and in this case it would be highly desirable to increase the carbon dioxide in the inspired air to, in part, counteract it. It is to be noted, however, that in relatively large compart-

ments considerable time may elapse before carbon dioxide accumulates to a dangerous degree and that with low compartment pressures it may not be possible to bring the concentration up to the desired level at once. The control of carbon dioxide depends on the rate of production and its elimination by ventilation.

Effects of Changes in Pressure

As has been previously pointed out, one of the great advantages of the pressure compartment is that under normal operating conditions the occupants will not be subject to disturbing mechanical effects resulting from low pressures or sudden change of pressure. The control of the compartment pressure to meet these conditions is therefore the object to be desired.

With respect to the oxygen requirements, it is possible to decrease the partial pressure in the inspired air slightly over that existing at ground levels without suffering from serious oxygen lack, so that barometric pressures lower than 760 mm. may be used, thus decreasing the pressure differential between the cabin and the surrounding atmosphere. The pressure to be maintained within the compartment will depend upon the duration of the flight and the concentration of carbon dioxide in the air.

Recently a great deal of speculation has arisen concerning the effect of a leak in a pressure compartment and a number of rumors have been circulating concerning the devastating consequences of a cabin rupture at high altitudes. The nature of the effects will, of course, depend upon the differential pressure and rate of loss of barometric pressure. If the leak is small and the rate slow, no harmful effects should be expected immediately, but an auxiliary oxygen supply should be available for such an emergency and the pilot should descend to lower levels at once. A sudden rupture of considerable magnitude would appear to be more serious, however, and in order to investigate this the following experiments were performed. An animal was sealed off at ground level in a tank contained with a high altitude chamber and the latter evacuated to an altitude pressure of 50,000 ft. A large rubber stopper was then pulled from the tank, thus elevating the animal to a 50,000 ft. altitude pressure in a few seconds. If the animal was immediately brought to ground level pressures, no harmful effects were apparent, but if permitted to remain at the elevated altitude for a period of time, autopsy showed copious bubble formation throughout the entire circulatory system. In the same manner, laboratory personnel have been brought to a 15,000 ft. altitude pressure in 0.01 seconds without experiencing harmful after effects. This corresponds to ascent at a velocity of over 100,000 m.p.h. These experiments show that due to the delayed action of bubble formation, a sudden rupture of considerable magnitude need not be regarded as a major catastrophe provided that lower levels can be reached before the symptoms of compressed air illness and anoxemia have time to become manifest.

Conclusion

From the foregoing, it becomes apparent that in order to take advantage of the higher speeds, weather conditions and improved riding qualities at the higher levels, it becomes necessary to provide the pilot and passengers with an environment which is independent of altitude and rate of change of altitude. The logical solution for these requirements is the pressure cabin in which it is possible to maintain surroundings which are conducive to the comfort and well being of the occupants under all conditions of flight.

The Influence of Aviation Medicine on Aircraft Design and Operation

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SUMMARY

ALL of the deleterious effects of flight are due either to the design or method of operation of the machine in which a flight is made. It is the responsibility of Medical Science to determine what these deleterious effects of flight are, but since it has neither the technical knowledge nor the authority to devise and employ the necessary remedial measures, this then becomes the responsibility of the airplane designer and operator.

INTRODUCTION

Aviation medicine is that branch of general medicine which deals with the comfort, health, and safety of those who fly. It is by no means limited to the examination of candidates for flying training and to the periodic re-examination of graduate pilots as so many seem to believe, but includes preventative medicine, industrial medicine, sanitation, epidemeology, and pure research, insofar as these sciences apply to aviation.

It was not until 1934 that aviation medicine was accorded its rightful place in aeronautics and for the first time allowed to exert its influence on the design and operation of aircraft. Up until that time it was generally considered that the careful selection and frequent re-examination of pilots were sufficient to assure the efficient operation of aircraft. Since that time, however, the U. S. Army Air Corps has recognized and has adopted a second principle with reference to the human element in flying. This second principle is based on a broader, longer-range view of the question than has heretofore been utilized. It recognizes the fact that the upper limit of quality that can be obtained in personnel has about been reached; that the most carefully selected personnel has a definite tolerance beyond which it is impossible to go without producing an immediate loss of efficiency and a gradual deterioration of the individual; and that with the increased speed, maneuverability, altitude performance, size, weight, and technical complications of modern aircraft that that tolerance is now being reached and in some cases exceeded.

In order that this question might be adequately studied, the Army Air Corps established a Physiological Research Laboratory at its Materiel Division, Wright Field, Dayton, Ohio. This laboratory was created to study the effect of flight on the human being and to make such recommendations to the proper agencies as were deemed necessary to improve the flying efficiency of Air Corps pilots through the development of equipment or through changes in aircraft design or operation which would eliminate, minimize, or neutralize those effects of a deleterious nature.

Most of the work that has been done at the laboratory applies to commercial as well as military aviation and the balance of this paper will be devoted to a brief discussion of some of the fundamental concepts of this phase of aviation medicine and a more detailed discussion of one or two specific problems which are today the center of heated medical, as well as aeronautical, controversies.

BY-PRODUCTS OF AIRCRAFT DESIGN AND OPERATION

Flight, in the sense of being poised above the earth's surface, is not harmful to the human and does not in itself constitute a medical problem. It is the machine in which we fly, or the manner in which the machine is flown that creates all of the known harmful effects of flying. Thus carbon monoxide gas, noise, and vibration do not naturally occur in the atmosphere but are deleterious by-products of aircraft design. Likewise acceleration, rate of climb, and high altitude are deleterious by-products of aircraft operation. These facts should serve to explain the interest of those in aviation medicine in aeronautical fields of which they possess no technical knowledge and to bring to the attention of the industry a realization of its responsibility for any undesirable conditions which exist and its responsibility to devise remedies for them.

It is probable that many of the undesirable characteristics of aircraft design and operation, with reference to the human element, may have been overlooked due to a lack of appreciation of their existence in some cases or a lack of appreciation of their significance in others. Some of the most pertinent information in aviation medicine is not known, or is not accepted, by the aviation industry because the aeronautical engineer is interested primarily in aircraft performance and not in the human element and since the two are naturally incompatible the latter is allowed to suffer at the expense of the former.

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Aviation always has been, and for a good many years will probably continue to be considered a spectacular occupation. It is associated in the mind of an emotional public with heroism and violent death. In such a surrounding of distorted ideas it is sometimes difficult to think clearly and to act intelligently. Actually commercial aviation today is rather commonplace. Its safety is twice as great as five years ago and approaches other modern means of transportation in this respect. If commercial aviation will agree that it has advnaced to this stage of development then it must also agree that it should now concentrate its efforts on the elimination of existing minor effects of flight which have heretofore been largely ignored.

It is deemed desirable at this time to point out that these minor problems of flight, which are to be discussed below, may not individually be of any considerable importance but it is believed that it can be shown that collectively they constitute a real problem and a real hazard. Furthermore, those things which may be considered impractical today are not to be recognized as such in this paper for to admit impracticability is to halt progress. It is to be remembered that not so long ago the airplane itself was the impractical dream of a visionary.

In considering the effects of flight on the human, there are two distinct and separate problems. First there are the acute effects which are the immediate results of a single flight and which may effect pilot and passenger alike; and second, the chronic effects which are the culminative results of a series of flights over a long period of time. These chronic effects are seen only in pilots because passengers seldom, if ever, fly frequently enough to show any deleterious effects. For the purpose of this paper the pilot has been selected for discussion for several reasons. In the first place, the pilot being in good physical condition should offer the best resistance to adverse conditions and any deterioration which may develop in him can be attributed solely to the effect of flight. Secondly, the pilot is engaged in flight over a period of time long enough to exhibit deteriorating effects which may not be manifested in a single flight. Third, the pilot is by far the most important person aboard an airplane since the success of the flight depends entirely on him. Fourth, the pilot is selected because he generally accepts the conditions of flight as a matter of course, is inclined to deny the existence of the ill effects of flight, yet insistently complains of "pilot fatigue."

Pilot Fatigue

Since the effects of flight are related to pilot fatigue as cause is related to effect, it may be well at this point to examine this term more closely. About four years ago attention of the aeromedical association was called to an abnormal fatigue among commercial pilots and a study made to determine the maximum number of hours that should be flown in any given period of time. Following this study, based principally on the statements of the pilots themselves, suitable recommendations were made and regulations put forth limiting the flying time of each pilot to an average of less than 3 hours per day. Despite this limitation on flying, crashes have continued to occur as a result of so called "pilot error" and certain pilots and pilot organizations still continue to complain of pilot-pushing and of being overworked. So insistent has this complaint been that this past year the Department of Commerce asked for and received from Congress a sum of money to further investigate this problem.

What Is Pilot Fatigue?

Strictly speaking pilot fatigue cannot be defined because the term fatigue itself is not capable of definition. No one knows what fatigue is and it cannot be measured. It is only known what some of the effects of fatigue are and some of the things which produce it. Broadly speaking, pilot fatigue is similar to doctors' or engineers' fatigue, or farmers' or ditchdiggers' fatigue. It is not in any sense an ailment without known cause or effect but is a clearly defined entity produced by a number of well understood environmental conditions acting over a period of time and resulting eventually in a culminative nervous and mental fatigue manifested by a diminished capacity for mental effort, a nervous irritability, a distaste for the job, and accompanied by a sensation of tiredness or exhaustion which may be physical as well as mental.

The question as to whether pilot fatigue actually exists or not has never been definitely proven. All of the evidence to date has been derived from the statements of the pilots themselves. The real proof however, since fatigue cannot be measured, must be derived from a study of the enviromental conditions of flight. If these conditions are such as to justify the opinion that an average exposure of less than three hours per day is sufficient to induce chronic fatigue then there must be something wrong with that environment. If such conditions cannot be shown to exist then it must be assumed that there is something wrong with methods of pilot selection.

What Are the Causes of Pilot Fatigue?

In order to properly understand some of the possible causes of pilot fatigue, it is necessary to review briefly some of the interesting facts of aviation medicine.

During the early part of the World War the British made no attempt to select specially qualified candidates for flying training and accepted anyone fit for general military duty. As a result, as high as 50 percent of their flying cadets developed a neurosis, or as it is more popularly known, a nervous breakdown, during flying training. In addition, 90 percent of their graduate pilots were killed as a result of what we now choose to

call "pilot error." This would indicate that flying produces a high degree of mental and nervous stress which quickly leads to the breakdown of the average person and is tolerated by the successful flyer only through the expenditure of a great amount of nervous energy. When the United States entered the World War it established a special medical section and a medical research laboratory to study the question of pilot selection in the hope that it might avoid the experience of the English. While this selection resulted in an improvement in the caliber of flying cadets the fact remains that even today after 20 years of effort 45 to 55 percent of the candidates for flying training are disqualified because of tenseness on the controls and other manifestations of fear in the air and more than 50 percent of the accidents in both the Army and in civil aviation are still attributed to "pilot error."

A second factor which must be carefully analyzed, before the question of pilot fatigue can be properly understood, is the truth or fallacy of the belief that the pilot is endowed with qualities which render him immune to fear, cold, pain, hunger, and the thousand and one other things from which the ordinary human readily succumbs. To determine definitely just what qualities pilots do, or do not, necessarily have, can readily be determined by a review of the requirements of the physical examination forms for flying. From these it is found that, from the physical standpoint, the pilot need only be normal and not in any respect super-normal. In the examination there are no tests to gage the courage of the individual. Neither is there a test to determine his tolerance to noise, to vibration, to carbon monoxide, to cold, or to high altitude. The reason it is so difficult to pass the physical examination for flying is that one must be physically normal in every respect, must possess a stable nervous system, and must be intelligent. Few combine these three attributes.

The reason it is so difficult to learn to fly is because one must be able to repress his instinct of self-preservation, his inherited fear of falling, and in addition must possess an inherent ability to learn to fly quickly and well, just as some individuals have an inherent ability to learn to play a musical instrument quickly and well.

From this it is obvious that a pilot is not required to demonstrate any unusual physical tolerance to stress. He must however have a high resistance to nervous stress and a high degree of intelligence. Unfortunately, in most cases, these latter factors do not tend to appear together to a high degree in the same individual and generally a compromise must be accepted. Intelligence is necessary in flying and has its advantages but it also has its disadvantages. A mind composed of fine quality fiber is normally also one of delicate fiber. The intelligent mind is more irritated by disagreeable sounds and situations and is more easily fatigued by bodily pain and discomfort than the dull mind. Intelligence recognizes the presence of danger and appreciates the value of safety. The higher the intelligence the more this is true. It is only the moron who is unconcerned.

With these facts in mind it is now possible to proceed to a discussion of the deleterious effects of present aircraft design and operation on the pilot and the end results which may be expected. These factors will only be briefly discussed, but what is to follow is based on adequate and reliable data and is not a mere matter of opinion. It is also to be noted that factors common to both military flying and commercial flying are included.

The Deleterious Factors in Aircraft Design

For the purpose of this paper, the term "aircraft design" will be used to include not only the airplane but also any auxiliary equipment or the lack of such equipment which contributes to undesirable environmental conditions of flight.

Wind, or more correctly the slip-stream, when allowed to come in contact with the exposed or partly exposed body, produces wind burn and chapping of the skin, irritates the eyes and interferes with vision, increases lung ventilation, and markedly increases the effect of cold. If strong enough it can directly produce tissue damage. Wind is a source of great annoyance and is a definite cause of fatigue.

Cold increases the body metabolism and consequently the energy output. It causes physical discomfort or actual pain, slows the physical and mental processes of the individual, destroys morale, and if severe enough leads to loss of judgment and even to delirium. It is followed by fatigue.

Too little or too much illumination or glare from shiny metal surfaces, from clouds, water, or snow produces eye strain. This is likewise produced by constant shifting of the gaze from near objects in the cockpit to objects far away on the ground and this is especially so at night with the cockpit lighted when the eyes must rapidly adjust for light and dark vision as well as for distances.

Noise has aptly been defined as an unpleasant sound. It originates in aircraft from the motor, the propeller, the slip-stream, and from the radio. It is a common observation that a sudden loud noise produces a sharp muscular response and a position of defense which may be followed by a sense of faintness or collapse. Every intelligent person knows that a noise is harmless and the explanation for this fear response lies in the fact that the fear of noise is one of the two inherited fears. If loud noises are continued long enough instead of a sudden muscular response there is a prolonged tenseness of the entire musculature with a consequent tiredness and fatigue. Noise is a potent source of annoyance and irritation to the nervous system.

Vibration, like noise, is known to produce fatigue and the mechanism at work here may be explained as follows. The motion of a ship at sea may be compared to an extremely coarse vibration. As the ship rolls all of the muscles of the body are involuntarily called into

play to maintain equilibrium and prevent a fall and painful injury. In vibrations, of a magnitude found in aircraft, each phase of the motion is transmitted to the brain as the beginning of a loss of equilibrium and the body is continuously tensed in preparation for the correction of an anticipated loss of balance.

Carbon monoxide, a product of incomplete combustion, and its symptoms, are too well known to need repeating here but it is desired to point out that repeated small doses are much more harmful than one single large dose. In a recent study of a large number of individuals in industry who suffered from chronic CO poisoning it was found that although they were physically able to continue their work they suffered from a gradual deterioration of the nervous system which in some cases amounted to idiocy.

Humidity, especially in a closed space, if low, will cause dryness and irritation of the mucous membranes of the respiratory system and a feeling of lassitude and oppression if it is too high.

Ventilation is necessary to supply fresh air and to remove the CO_2 of the breath and disagreeable odors.

The cockpit and its equipment represents the work shop of the pilot and the tools with which he has to work. The seat and the controls may be poorly arranged and with insufficient adjustment for comfort. The windshield may distort vision and visibility may be bad.

Considering the duties of the pilot, it is obvious that in the larger aircraft there is more to do than can be expected of an individual without the possibility of error occurring, especially under adverse conditions. The multiplicity of instruments, gages, valves, levers, switches, buttons, wheels, knobs, and gadgets that the modern cockpit contains are legion. The old problem of handling the stick, rudder, and throttle has given way to a multiplicity of duties which are as diverse as they are intricate. Not only are there twenty to forty instruments to be checked but there are flaps and landing gear to be operated, throttle, mixture control, manifold pressure, and propeller settings to adjust, radio communications to be maintained, navigation problems to be worked, and fuel consumption, ground speed, drift, and other calculations to be carried on in flight.

To carry out this program successfully the pilot must concentrate his attention as best he can on many individual problems and pass successively from one to another and thereby is exposed to all of the classic elements for incurring mental fatigue.

Pilot Error

This brings us to the question of "pilot error." "Pilot error" may be defined as any accident which would not have occurred had the airplane been flown by a perfect pilot. The reason given for utilizing the perfect pilot as a standard for comparison in accident statistics is that it is the only method by which statistical data can be properly evaluated. While there can be no quarrel with statistics in general, it certainly seems a grave mistake to accept statistical data which are based on a false premise to begin with and consequently give an entirely false impression of what would otherwise be an obvious fact.

It must be remembered that every pilot who is involved in a crash due to "pilot error" is sitting in the nose of the airplane and is the first to hit. It is to be assumed that, since his life is at stake, he does all that is he capable of to protect himself. Should he fail there can only be four explanations which may be considered valid. If it is shown that the pilot was not mentally or physically fit, then the flight surgeon who is charged with his care is at fault and the accident should be charged to "doctor's error." If it can be shown that the pilot was lacking in flying technique or experience then the accident should be charged to "employment manager's error." If it can be shown that any of his equipment failed then the accident should be charged to "material failure." Finally if it can be shown that the accident was due to a multiplicity of duties which might cause him to forget, to make an erroneous calculation, or to overlook a fact which would have been obvious under less trying conditions then the accident should be charged to "airplane designer's error."

The number of accidents which have occurred in recent years and charged to "pilot error" are by no means an index of the number of errors committed in flight for it is only in the mountainous regions of the country where the clouds have solid "cores" that such errors are brought to our attention.

The Deleterious Factors in Aircraft Operation

From the operating standpoint, there are also many factors conducive to fatigue. "Operation," for the purpose of this paper, is defined as the manner in which an aircraft is flown whether dictated by government regulations, by operating company policies, or by the whims of the pilot.

Night flying is more fatiguing than day flying because of the difficulty of orientation and the inability to see clearly either the terrain or other objects in the air. Blind flying is extremely fatiguing for the same reason plus the need for concentration on the instruments and because of a tendency for most pilots to become disoriented in space and to become slightly air sick in rough air. It has repeatedly been demonstrated that what one sees and what one feels during blind flight are two distinct and contrary sensations which lead to mental confusion.

Blind flying is a good example of what has been termed an aid to flying with the implication that it is an aid to the pilot. As a matter of fact this, plus most all of the other aids to flying, are simply an aid to operations and an added burden to the pilot. Without blind flying equipment, flying would not be attempted in ad-

verse weather. Likewise flaps do not slow the modern airplane down to the landing speed of the older planes, but simply to a landing speed less than it would have without it. Today the pilot lands faster than ever before and has an extra mechanism to work. The point being stressed is that with each improvement in the airplane there occurs a relative loss of efficiency of the pilot.

Acceleration is not a serious problem in commercial aviation as far as the pilot is concerned but passengers suffer considerably from angular accelerations by becoming air sick. In military aviation centrifugal accelerations are a matter of considerable concern due to the fact that temporary blindness or unconsciousness occurs from high positive accelerations and hemorrhage of the brain from high negative accelerations. Linear accelerations are well tolerated by the well supported body and it has recently been demonstrated at the Army Air Corps, Materiel Division that a terminal velocity of 220 m.p.h. can be attained in 1 second without injury to personnel.

Oxygen-Want

Operation at the higher altitudes produces a condition of oxygen-want in the body. Oxygen is the most vital of the bodily requirements and death (unless one is burned alive) is always ultimately due to a lack of oxygen in the tissue cells. While the lack of food and water may be tolerated for days, oxygen must be supplied almost continuously and in adequate amounts, for the body only carries a reserve of approximately 400 cc., sufficient for about $1^1/_4$ minutes.

Oxygen is a normal constituent of atmospheric air and at all altitudes constitutes 21 percent of it. Since oxygen follows Dalton's law of gases it exerts a partial pressure equivalent to that which it would exert if it occupied the whole of the space alone. Therefore, under standard conditions oxygen exerts 159 mm. Hg pressure. However, in the lungs it exerts a partial pressure of only 100 mm. Hg due to the presence in the lungs of a water vapor pressure of 47 mm. Hg and a CO_2 pressure of 40 mm. Hg.

As one ascends above sea level the atmospheric pressure becomes less and consequently the partial pressure of oxygen becomes less. This change is such that the partial pressure of atmospheric oxygen is reduced by $^1/_4$ at 7700 ft., $^1/_2$ at 17,980 ft., and $^3/_4$ at 33,300 ft. The lung oxygen partial pressure decreases more rapidly than the atmospheric oxygen, however, on account of the increasing percent of water vapor and CO_2 in the lungs so that when the atmospheric oxygen is reduced by $^1/_3$ the lung oxygen is reduced by $^1/_2$. The reduction of oxygen partial pressure in the lungs at altitude causes a slower diffusion of this gas into the blood and very early it is found that the latter is only partially saturated and the body cells begin to suffer from oxygen-want. The point at which this oxygen-want should be relieved in the pilot is at the present time the object of a heated controversy in aviation as well as medical circles. That such a problem should be a question for dispute is *not* due to a lack of knowledge of the subject, but to a variety of other causes which range from the sublime to the ridiculous.

Attitude of the Pilot

One of the most important of the latter type is the attitude of the pilot. During the World War due to the lack of oxygen equipment all Army pilots were given an altitude classification test in order to select those best suited for pursuit work. The test consisted of subjecting each individual to an increasing simulated high altitude until he was in a state of mental and physical collapse and that point was taken as the altitude to which he could fly. Naturally a friendly spirit of rivalry sprang up and great efforts were exerted to get a high rating. With the advent of oxygen equipment and the realization that a helpless pilot was a poor risk the altitude classification test was abandoned but unfortunately the tradition lingers on and today the average pilot clings to the old idea that it is "smart" to go to high altitude without oxygen.

A second factor is the difficulty in convincing the pilot that he is inefficient at high altitude. Oxygen-want acts very much like alcoholism. In most cases the more one is affected the better one feels. It affects judgment and memory and one who is under its influence is not responsible for his actions or for his subsequent statements. It is regrettable that oxygen-want is not an extremely painful process.

A third factor is the unwillingness of the aeronautical engineer to sacrifice pay load of the airplane for the welfare of the pilot.

From the strictly medical standpoint the specific altitude above which oxygen should be administered to pilots cannot now or can it ever be answered by a single, simple statement. It varies with the individual, the altitude at which he resides, the rate of climb, the duration of the flight, the frequency of flights, and the lapse of time since a previous flight at altitude.

As stated above, altitude tolerance tests have shown great variations in individuals. In the absence of these tests it is necessary to provide for everyone on the basis of the lowest possible tolerance which may exist in the organization. At the Materiel Division it has been determined that the effect of oxygen-want is not only proportional to the altitude but also to the time spent at any altitude. It has been determined that flights of long durations at altitudes as low as 8000 ft. have produced a profound fatigue which requires 48 hours for recovery. Other studies at the Materiel Division which are not yet complete, indicate that relatively mild degrees of oxygen-want are much more serious than was previously thought and that it is certainly one of the most prominent causes of pilot fatigue. If the aero-

nautical industry finds that the administration of oxygen at reasonable altitudes is impracticable let those who find it so be advised that it is desirable, and end for all time the perennial effort to induce medical science to perjure itself in an attempt to reconcile what should be done with what can be done.

Changes of altitude through the present-day range of operation are important principally due to the effect on the ears and the nasal accessory sinuses. This not only causes discomfort or in some cases actual pain because of difficulty in equalizing the pressure in these cavities with that of the surrounding atmosphere, but in the case of the ear is thought to be the principal cause of the deafness which is an occupational disease among pilots.

The Results of Pilot Fatigue

Having recounted briefly some twelve to fifteen known causes of fatigue to which the pilot is repeatedly exposed, it remains to be shown that these factors do in fact affect the pilot adversely. Considering the fact that the pilot begins his career in perfect physical condition and with an especially stable nervous and mental system, it should be expected that under ordinary circumstances he would proceed through life with a minimum of physical, mental, and nervous disturbance. Various studies have shown, however, that this is not true. It has been shown in one study for example that 11 percent of the pilots suffered from a mild form of functional neuroses. A smaller percentage suffer from various acute neuroses such as anxiety or compulsion neuroses and become totally and permanently incapacitated. Still others give way to a complete mental breakdown in the form of one of the psychoses.

From the physical standpoint there is an abnormal rate of deterioration which results in a retirement at an age approximately ten years earlier than would normally be expected.

It is believed that these facts are adequate to prove the existence of pilot fatigue and deterioration and demonstrate the urgent need for the airplane designer to accord more emphasis in the design of the airplane to dealing with this very real problem.

If, by emphasizing specific design preparation so that noise, vibration, CO, glare, anoxemia, and other similar factors were progressively reduced in airplane cockpits from year to year and the cockpit equipment simplified or the crews enlarged so that the pilot's task was simplified, it is believed that more hours could be flown per pilot and with greater safety. It is believed that there would be a reduction of pilot error with fewer crashes, less loss of life and equipment with greater revenue from a more confident public. It is believed that there would be a less rapid turnover of labor with an increase in length of useful service of pilots and that they would lead a longer and healthier life.

Conclusion

It is impossible for medicine to do more than to study the effects of flight and to make proper recommendations. It has neither the power nor the knowledge to carry out those things which it feels should be done. It is hoped that those who are in a position to remedy the existing conditions will devote a proportionately greater amount of effort to improve this phase of aviation. Today the human element in flight is relatively the weakest link. It is weak only because too much has been demanded of it. No campaign for safety or progress can be successful until that link has been proportionately strengthened.

Flight Analysis of the Sounding Rocket

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January 26, 1938

Introduction

IN ATTEMPTING to reach altitudes above those obtainable by sounding balloons, the rocket motor may be utilized to propel a suitable body. In this analysis a wingless shell of revolution will be considered in vertical flight.

It was felt that, before entering into practical experimentation, it was desirable to have a preliminary performance analysis based on simplified assumptions, using the most recent data for air resistance at high speeds. As a matter of fact, this analyis was completed without the knowledge of a similar investigation.[1] However, as this treatment is more general in discussing the influence of the design parameters and more suitable for application to particular cases, the authors believe it is worth while to present the analysis.

The equations of motion for flight *in vacuo* have been included to show the optimum performance and for comparison purposes. After developing similar expressions for flight with air resistance, a series of calculations was carried out using the method of step-by-step integration. The dimensions of the rocket chosen were felt to be feasible for practical construction. The motor efficiencies for the two cases were chosen to match closely the reported results of R. H. Goddard[2] and Eugen Sänger.[3]

The calculations have not been extended to further cases, as the amount of labor that would be required was not felt justified at the present time.

Assumptions and Notation

Throughout this analysis, the assumption will be made that the rocket motor supplies a thrust of constant magnitude for the period of powered flight. This means that the rate of flow of combustibles and the effective exhaust velocity remain constant. This assumption is of a conservative nature, as theoretical considerations show that the thermal efficiency of the rocket motor and, therefore, the thrust, will increase as the ratio between chamber pressure and exhaust pressure increases.

It has been assumed that the acceleration due to gravity remains constant. This assumption is also conservative.

The following notation has been used for the quantities involved:

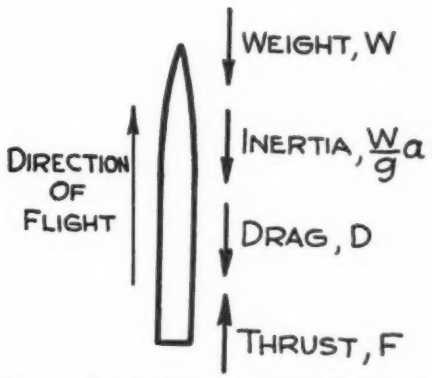

FIG. 1. Forces acting on a rocket in vertical flight.

F	=	thrust in lbs.
m	=	mass of exhaust gases flowing per second
c	=	F/m = effective exhaust velocity in ft./sec.
W_0	=	initial weight of rocket, lbs.
W	=	instantaneous weight of rocket, lbs.
W_{FO}	=	weight of fuel and oxidizer carried, lbs.
ζ	=	W_{FO}/W_0, ratio of weight of fuel plus oxidizer to initial weight of rocket
a_0	=	initial acceleration, ft./sec.^{2}
a	=	instantaneous acceleration, ft./sec.^{2}
g	=	acceleration of gravity, ft./sec.^{2}
V	=	instantaneous velocity, ft./sec.
V_s	=	velocity of sound, ft./sec.
h	=	altitude above sea level, ft.
t	=	time, sec.
A	=	largest cross-sectional area of rocket, sq. ft.
D	=	drag due to air resistance, lbs.
σ	=	air density ratio
ρ_0	=	mass density of air at sea level

In Fig. 1 the forces acting on the rocket in vertical flight are shown.

Summing the forces:

$$\Sigma \text{ Forces} = 0 = F - W - D - (W/g)a \qquad (1)$$

The thrust developed by the motor is expressed by

$$F = mc \qquad (2)$$

Then from Eqs. (1) and (2):

$$a = (mc - W - D)g/W \qquad (3)$$

If the rate of flow of combustibles is constant during powered flight, one can write:

$$W = W_0 - mgt \tag{4}$$

At the start of the flight,

$$W = W_0,\ a = a_0,\ V = 0,\ D = 0 \tag{5}$$

Then Eq. (3) becomes

$$a_0 = (mc - W_0)g/W_0 \tag{6}$$

and

$$m = W_0(a_0 + g)/cg \tag{7}$$

Eq. (3) can now be evaluated, using Eq. (4) and Eq. (7), and for the acceleration at any instant

$$a = -g + \frac{(a_0 + g)}{1 - \dfrac{t(a_0 + g)}{c}} - \frac{g}{1 - \dfrac{t(a_0 + g)}{c}} \frac{D}{W_0} \tag{8}$$

Flight *in Vacuo*

With no air resistance, the third term of Eq. (8) vanishes so that

$$a = \frac{dV}{dt} = -g + \frac{(a_0 + g)}{1 - \dfrac{t(a_0 + g)}{c}} \tag{9}$$

Integrating Eq. (9) one has, for the velocity at any instant:

$$V = \frac{dh}{dt} = -gt - c \log\left[1 - \frac{t(a_0 + g)}{c}\right] + V_0 \tag{10}$$

Integrating Eq. (10) one has, for the height at any instant:

$$h = -\frac{1}{2}gt^2 + ct + \left(\frac{c^2}{a_0 + g} - ct\right) \log\left[1 - \frac{t(a_0+g)}{c}\right] + V_0 t + h_0 \tag{11}$$

The maximum acceleration and maximum velocity will occur at the time that the fuel is exhausted. The time at which thrust ceases is expressed, using Eq. (4), by the relation

$$(1 - \zeta)W_0 = W_0 - mgt_p \tag{12}$$

Introducing Eq. (7) into Eq. (12), one obtains, for the duration of powered flight:

$$t_p = \zeta c/(a_0 + g) \tag{13}$$

If, at the start of the flight, $V_0 = 0$ and $h_0 = 0$, then

$$a_{max.} = -g + \frac{a_0 + g}{c - \zeta} \tag{14}$$

$$V_{max.} = -c\left[\frac{g\zeta}{a_0 + g} + \log(1 - \zeta)\right] \tag{15}$$

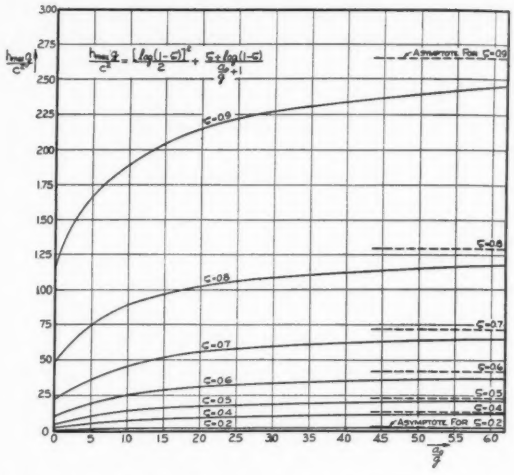

Fig. 2. Variation of $h_{max.}g/c^2$ with a_0/g for various ζ for flight *in vacuo*.

The maximum height reached will be the sum of the height at the time the fuel is exhausted and the height resulting from coasting. The height resulting from coasting is given by the expression:

$$h_c = V_{max.}^2/2g \tag{16}$$

Adding this to Eq. (11) and evaluating t_p from Eq. (13), the maximum height reached is

$$h_{max.} = \frac{c^2}{g}\left\{\frac{[\log(1 - \zeta)]^2}{2} + \frac{\zeta + \log(1 - \zeta)}{(a_0/g) + 1}\right\} \tag{17}$$

Eq. (17) shows that three parameters determine the rocket performance *in vacuo*. They are a_0, ζ, and c. In Fig. 2 the variation of $h_{max.}\,g/c^2$ is plotted for various values of a_0/g and ζ. The importance of having a large percentage of combustibles is clearly shown. The initial acceleration, a_0, is important until values in the neighborhood of $6g$ are reached.

Flight through a Resisting Medium

Considering flight through the air, the drag of the rocket can be expressed in the form

$$D = \rho_0 \sigma V^2 C_D A/2 \tag{18}$$

which, substituted in Eq. (8), gives

$$a = -g + \frac{(a_0 + g)}{1 - \dfrac{t(a_0 + g)}{c}} - \frac{g\rho_0\sigma V^2}{2\left[1 - \dfrac{t(a_0 + g)}{c}\right]} \cdot \frac{C_D A}{W_0} \tag{19}$$

This is the fundamental equation for vertical rocket flight. In addition to the performance parameters for flight *in vacuo*, the ratio $C_D A/W_0$ also has important significance in the construction of the sounding rocket. As it appears in a term which reduces the acceleration of the rocket, it should be as small as possible. A rocket

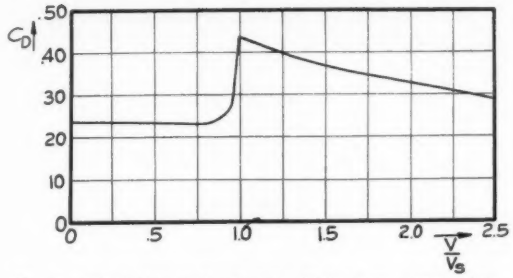

FIG. 3. Variation of the drag coefficient, C_D, with V/V_s.

of given initial weight should have as small a cross-section as possible and be of a shape that minimizes the drag coefficient.

As the density ratio, σ, and the drag coefficient, C_D, will be subject to great changes during flight, and are difficult to express accurately analytically, two ways of solving Eq. (19) are open. First, approximations can be made for the variation of σ and C_D to make an analytic solution possible, or second, a step-by-step method of integration of any degree of accuracy can be applied. The first method is quite likely to lead to extremely large errors, so that the second method has been chosen.

The variation of σ with height was obtained from references (4) and (5). The variation of C_D with the velocity of flight was taken from reference (6). It has been assumed, due to the lack of information, that the drag of the rocket was identical to the drag of a shell without a jet issuing at its base. The variation of the drag coefficient is reproduced from reference (6) in Fig. 3.

To describe the rocket flight, the following equations were used in the numerical calculations:

$$a_n = -g + \frac{(a_0 + g)}{1 - \frac{t_n(a_0 + g)}{c}} - \frac{g\rho_0\sigma_n V^2_{n-1}}{2\left[1 - \frac{t_n(a_0 + g)}{c}\right]} \cdot \frac{C_D A}{W_0} \quad (20)$$

$$V_n = V_{n-1} + a_{n-1}\Delta t \quad (21)$$

$$h_n = h_{n-1} + V_{n-1}\,\Delta t + (a_{n-1}/2)(\Delta t)^2 \quad (22)$$

where

Δt = time interval under consideration
n = number of the interval in the r steps of the calculation

The acceleration during coasting is given by

$$a_{c_n} = \frac{F_c}{m} \quad (23)$$

where

F_c = weight of the empty rocket plus air resistance or

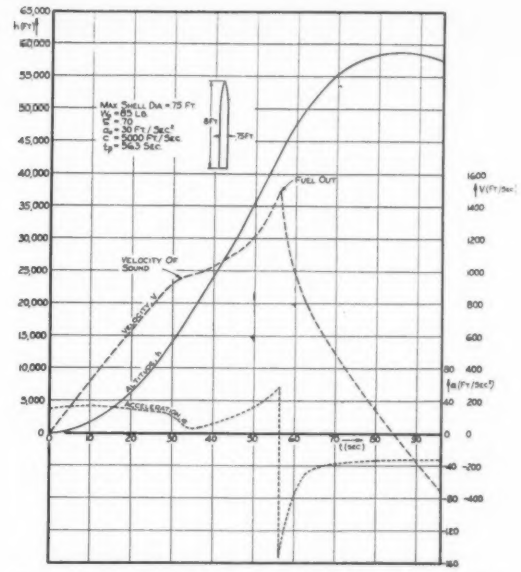

FIG. 4. Rocket performance for flight with air resistance, using a motor giving an effective exhaust velocity of 5000 ft./sec.

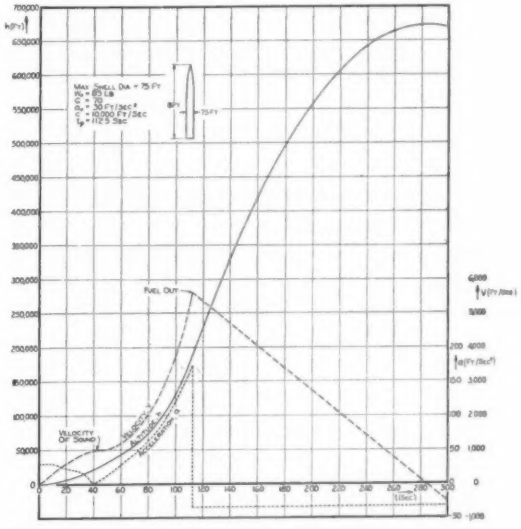

FIG. 5. Rocket performance for flight with air resistance, using a motor giving an effective exhaust velocity of 10,000 ft./sec.

$$a_{c_n} = -\left[g + \frac{\rho_0\sigma_n V^2_{n-1}\, g}{2(1 - \zeta)} \frac{C_D A}{W_0}\right] \quad (24)$$

In the following results to be presented, it was necessary to select dimensions of what may be called a typical sounding rocket. Therefore, the results will apply only to rockets having the same value of the ratio $C_D A/W_0$. For rockets with a different value of the ratio, this analysis serves only as a guide to the performance to be expected.

In Fig. 4 are shown the performance curves of a rocket with $c = 5000$ ft./sec., $\zeta = 0.70$, and $a_0 = 30$ ft./sec.^{2}. The retarding influence of the air is made evident

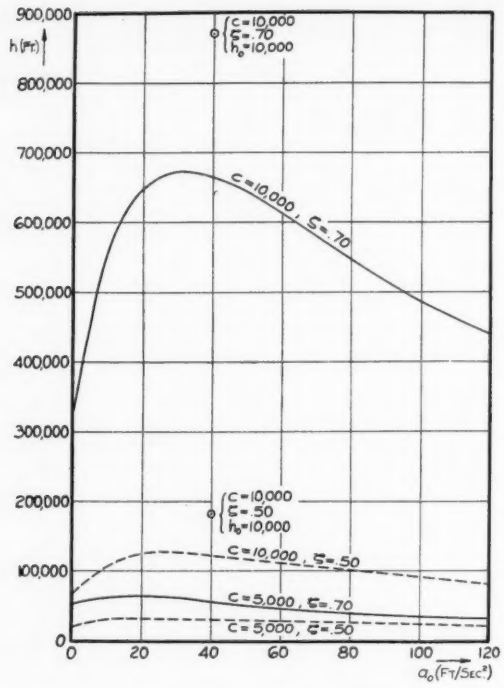

FIG. 6. Effect of a_0 on altitude to be reached for several performance parameter combinations.

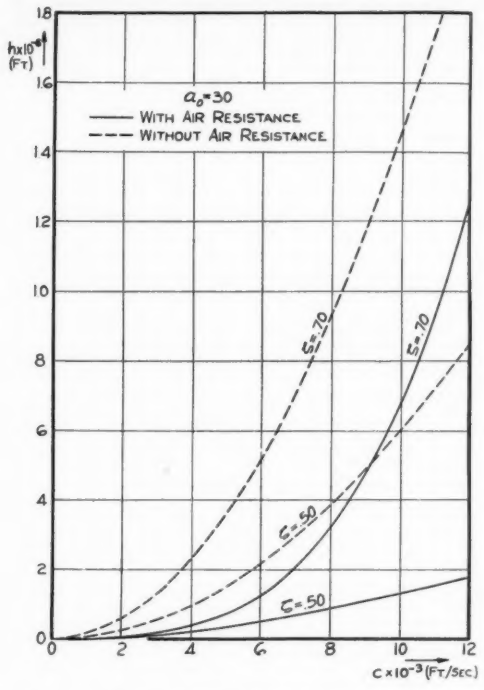

FIG. 7. Variation of altitude with c for $a_0 = 30$, with and without air resistance.

by the decrease in the acceleration as the velocity of sound is approached. The high density of the air at the time the fuel was exhausted prevented the rocket from coasting very high.

The performance curves shown in Fig. 5 are those for an identical rocket, but with a much more efficient motor which gives an exhaust velocity, c, of 10,000 ft./sec. For the same amount of thrust, the rate of flow of combustible is much smaller, so that the period of powered flight is greatly prolonged. This allows the rocket to get over the hump of the drag curve, and also to travel through less dense air. The velocity at the end of the powered flight will thus be much higher than before, causing the rocket to coast to a much higher altitude.

In Fig. 6 the variation of altitude with the initial acceleration is shown for the two cases. The importance of a high value of the exhaust velocity, c, is clearly evident. This shows that effort should be directed to develop a motor of high efficiency before flight attempts are made.

This figure also shows that there is a definite initial acceleration corresponding to the maximum possible height. This differs from flight *in vacuo* for which the height reached continually increases with the initial acceleration (see Fig. 2). A high velocity of flight through the dense lower levels of the atmosphere causes the combustibles to be rapidly "eaten up." The advantage to be gained by starting the rocket from a high point is shown in the figure by the calculated height for a rocket started from an initial altitude of 10,000 ft.

The variation of maximum height to be reached with the exhaust velocity, c, for flight *in vacuo* and in air, is shown in Fig. 7. This figure clearly illustrates the amount of height lost due to resistance of the air.

Higher altitudes may be reached by using the step-rocket. A rocket made up of three steps, respectively, of 600, 200, and 100 lbs., the lightest being fired last, with c of 10,000 ft./sec., a_0 of 40 ft./sec.^{2}, and ζ for each step of 0.70, starting from sea level, reaches a calculated altitude of 5,100,000 ft. and a maximum velocity of 11,000 m.p.h.

This analysis definitely shows that, if a rocket motor of high efficiency can be constructed, far greater altitudes can be reached than is possible by any other known means.

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Note on the Effect of Hydrogen/Carbon Ratio of Fuel on the Validity of Mollier Diagrams for Internal Combustion Engines

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THE possibility of using a Mollier diagram or its equivalent in investigating the various cycles of internal combustion engines has recently been pointed out.[1,2] Like the steam engineer, the automotive engineer can, by the use of graphs representing the thermodynamic properties of the working fluid in the engine at any state, solve many problems in internal combustion engines without going into the tedious computations which formerly characterized these solutions.

The thermodynamic-property charts or Mollier diagrams which have been published (*loc. cit.*) were constructed for octane which has a hydrogen/carbon ratio[3] of 2.25. The question arises as to whether the same charts can be used without too great an error for fuels with hydrogen/carbon ratios other than 2.25. With the increasing demand for high-octane fuels, the process of cracking as applied both to the production of gasoline from gas oil and to the reforming of naphthas of too paraffinic a structure, has come into increasing use. The products of cracking, in comparison with straight-run gasoline, are found to contain a higher percentage of saturated cyclic compounds (naphthenes) C_nH_{2n}, of aromatic compounds $C_6H_5C_nH_{2n+1}$, and of olefines C_nH_{2n}. All these compounds have hydrogen/carbon ratios less than 2.25. The actual value of this ratio can be determined from a careful exhaust gas analysis or by a fuel analysis; for present-day fuels it will be found to be not far from 2.1.[4]

In order to determine the effect of the change in fuel composition from $(CH_{2.25})_x$ (octane) to $(CH_2)_x$ (naphthenes and olefines), a new thermodynamic-property chart for fuel of the latter composition has been constructed. The values of cyclic efficiency and mean effective pressure for a standard Otto cycle were then obtained from the old and the new charts, and have been compared.

The new octene chart has been constructed for a richer mixture ratio corresponding to 85 percent theoretical air. The method of calculating composition of the combustion products is the same as outlined in Appendix B of a previous paper.[1]

For a mixture containing 85 percent theoretical air, the mols. of total oxygen per carbon atom in the system is 1.275 for $(CH_2)_x$ as compared with 1.329 for $(CH_{2.25})_x$. There is 0.0799 lb. of fuel per lb. of air for octene as compared with 0.0782 for octane. A summary of the results of the calculations leading to the construction of the chart is given in Tables 1 and 2. Table 1 shows the compositions, Table 2 the other properties of the equilibrium mixture.

TABLE 1

Computed Compositions of Products of Combustion of $(CH_2)_x$ with 85 Percent of Theoretical Air
(Numbers given are partial pressures, lbs./sq.in.)

Temp. Deg. R.	Pres. Lb./In.^{2}	N_2	H_2	H_2O	NO	CO	CO_2	O_2	OH	H	O
5400	1708	1200	20.9	226.7	2.276	97.8	152.7	.2825	4.98	.760	.0625
5400	854.5	600	10.6	112.7	1.578	49.4	75.9	.2880	3.46	.541	.0631
5400	385.7	270	5.0	50.3	1.010	23.0	33.4	.2424	2.25	.372	.0580
5400	186.4	130	2.6	24.0	.636	11.7	15.5	.2045	1.49	.268	.0532
4680	1702	1200	21.3	228.5	.263	91.8	158.6	.0115	.90	.184	.0026
4680	851.1	600	10.8	114.0	.183	46.3	79.0	.0111	.63	.131	.0026
4680	184.4	130	2.3	24.6	.086	10.1	17.0	.0096	.28	.060	.0024
3960	850.3	600	12.0	113.1	...	44.35	80.75	...	.060	.0202	...
3960	425.2	300	5.97	56.6	...	22.20	40.38	...	.042	.0144	...
3960	84.94	60	1.20	11.2	...	4.40	8.12	...	.019	.0064	...
3240	85.03	60	1.45	11.07	...	4.16	8.36	...	...	...	...
2520	85.03	60	1.96	10.56	...	3.67	8.85	...	...	...	...
1800	85.03	60	3.07	9.445	...	2.57	9.945	...	...	...	...
1440	14.70	10.4	.70	1.468	...	.284	1.884	...	...	...	...

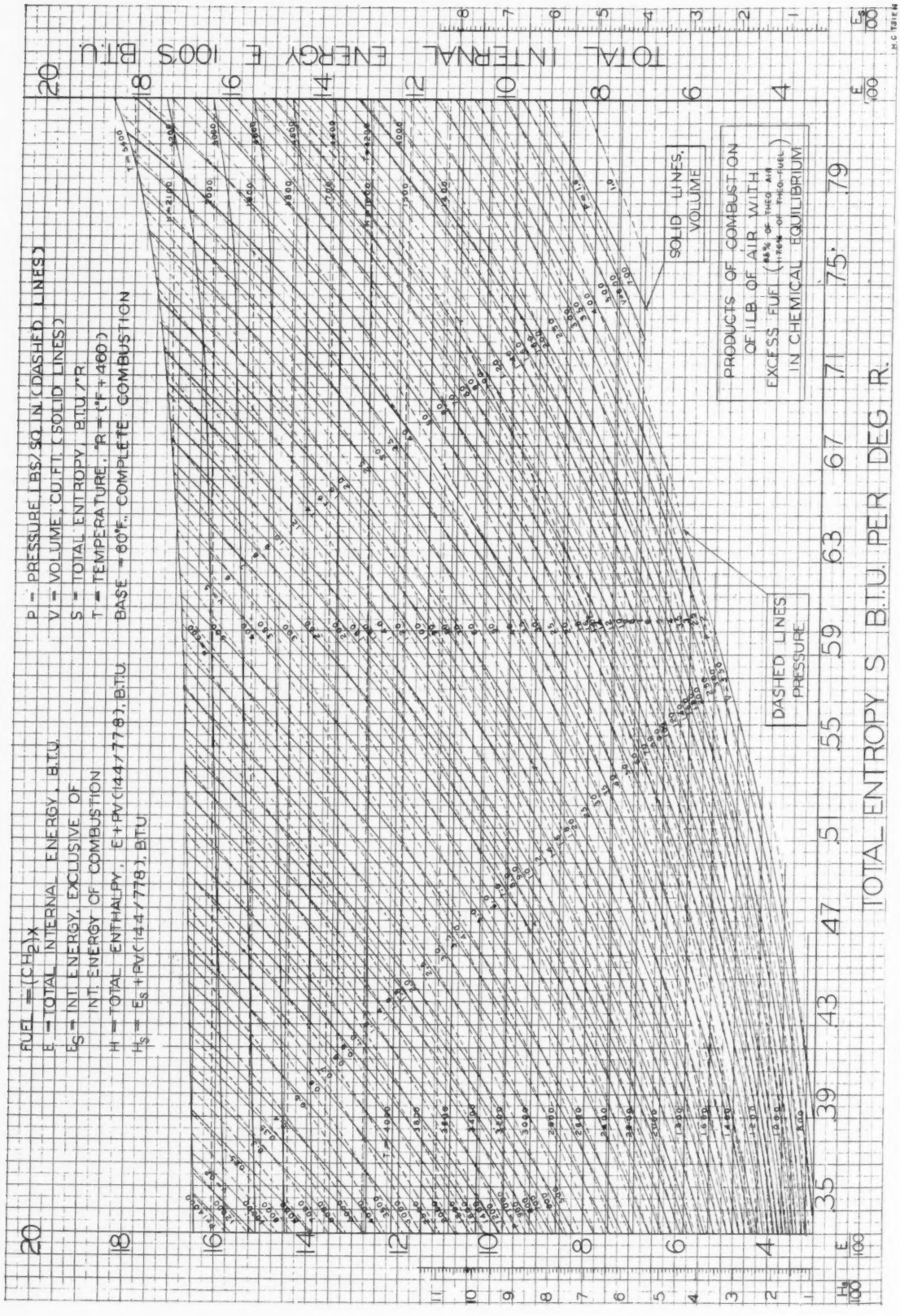
FUEL = $(CH_2)_X$
E = TOTAL INTERNAL ENERGY, B.T.U.
E_S = INT. ENERGY, EXCLUSIVE OF INT. ENERGY OF COMBUSTION
H = TOTAL ENTHALPY, $E+PV(144/778)$, B.TU.
$H_S = E_S + PV(144/778)$, BTU
P = PRESSURE, LBS./SQ. IN. (DASHED LINES)
V = VOLUME, CU. FT. (SOLID LINES)
S = TOTAL ENTROPY, BTU./°R
T = TEMPERATURE, °R = (°F + 460)
BASE = 60°F., COMPLETE COMBUSTION
TOTAL INTERNAL ENERGY E 100's BTU
TOTAL ENTROPY S B.T.U. PER DEG R.
SOLID LINES, VOLUME
DASHED LINES PRESSURE
PRODUCTS OF COMBUSTION OF 1LB OF AIR WITH EXCESS FUEL (LBS. OF THEO. AIR / LBS. OF THEO. FUEL) IN CHEMICAL EQUILIBRIUM

FIG. 1. Thermodynamic properties of the products of combustion of one pound of air with excess fuel (octene) in chemical equilibrium.

TABLE 2

Calculated Thermodynamic Properties of the Equilibrium Mixture of the Combustion Products of One Pound of Air with Octene, in the Proportion 117.6 Percent of Theoretical Fuel (or 85 Percent of Theoretical Air)

Temp. Deg. R.	Pressure P Lb./In.²	Volume V Cu. Ft.	Internal Energy E, B.t.u.	Entropy S B.t.u./ Deg. R.
5400	1708	1.320	1671	0.5254
5400	854.5	2.640	1680	.5800
5400	385.7	5.866	1700	.6467
5400	186.4	12.20	1731	.7088
4680	1702	1.145	1427	.4645
4680	851.1	2.290	1431	.5184
4680	184.4	10.58	1434	.6371
3960	850.3	1.935	1202	.4529
3960	425.2	3.870	1204	.5063
3960	84.94	19.35	1202	.6303
3240	85.03	15.85	986	.5547
2520	85.03	12.32	780	.4630
1800	85.03	8.81	582	.3438
1440	14.70	40.70	488	.4010

From Table 2, by suitable intermediate plots for interpolation, a thermodynamic-property chart was finally constructed (Fig. 1). This is to be compared to Fig. 4 of reference 1.

Two questions now arise:

(1) What is the effect, on thermal efficiency and mean effective pressure, of using $(CH_2)x$ instead of $(CH_{22.5})x$, when the compression ratio, percent of theoretical air and intake pressure and temperature are kept constant?

(2) If one is using $(CH_2)x$, what error is introduced by ignoring the fuel composition and using the older chart (for octane) to determine efficiency and mean effective pressure?

Consider first question (1). Let the condition be as in the example on page 417 of reference 1, where the compression ratio is 6:1 and the fresh charge enters at 90°F. and 14.7 lbs. per sq.in., with no throttling. Using octane (net heating value = 19,240 at constant pressure, 19,270 at constant volume) as a fuel and using the octane chart (Fig. 4, reference 1), the steps in the calculation appear as column 3 of Table 3. The cyclic efficiency is found to be 32.0 percent, the m.e.p. 181.5 lbs./sq.in. Using octene (net heating value = 19,154 at constant pressure, 19,182 at constant volume) (f) as a fuel and using the octene chart (Fig. 1, this note), the steps in the calculation appear as column 4 of Table 3. The cycle efficiency is found to be 32.7 percent, the m.e.p. 188.5 lbs./sq.in. The effect of fuel composition, in the range of variation met in practice, is seen to be almost negligible.

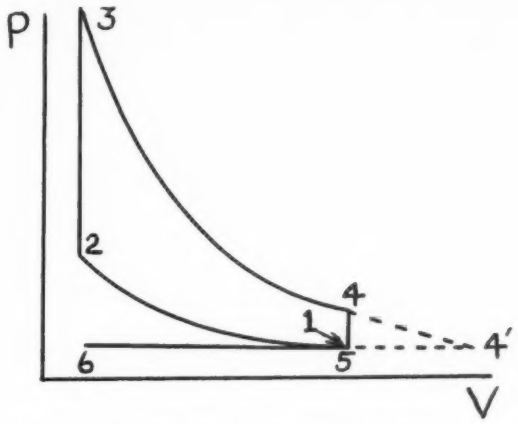

FIG. 2. Ideal pressure-volume diagram for unthrottled Otto cycle.

Consider now question (2). Let the compression ratio and intake temperature and pressure remain the same as before. Suppose octene is actually used as a fuel but that the octane chart is used for the calculation (although the heat of combustion is of course taken as that of octene. The steps are given in column 5, Table 3. The cycle efficiency is 31.7 percent, *versus* 32.7 percent when the correct chart is used; the m.e.p. is 181.2 lbs./sq.in. *versus* 188.5 when the correct chart is used. These small differences indicate that, except for unusual problems, one is justified in using the originally published charts for various octane–air mixtures, even though the fuel composition is known to vary somewhat from that of octane.

HEAT OF COMBUSTION

The best data on heats of combustion of hydrocarbons are those of Rossini,[5] who has shown that the gross heat of combustion of gaseous olefines at 25°C. at constant pressure is given by:

$$-\Delta H = A + 157.0n + B \qquad (1)$$

where $-\Delta H$ = heat of combustion per gram mol. of $(CH_2)n$
A = constant
n = number of carbon atoms
B = correction which is zero for $n \geq 5$

The heats of combustion of ethylene C_2H_4 and propylene C_3H_6 were found by Rossini to be 336.28 and 491.82 kilocalories per gram mol. and the corresponding B's were reported as $+1.3$ and -1.0, respectively,[6] the value of A was then found from Eq. (1) to be 21.98 and 21.82 using the data on ethylene and propylene, respectively. The heat of combustion of octene is therefore,

$21.9 + 157.0 \times 8 = 1{,}277{,}900$ calories per gram mol.

TABLE 3

Comparison of Results

Point	Property	Octane Fuel, Using Octane Chart	Octene Fuel, Using Octene Chart	Octene Fuel, Using Octane Chart
1	T assumed	643	635	640
	f assumed	0.042	0.0412	0.042
	V	16.5	16.45	16.58
	P	14.7	14.7	14.7
	E_s	24	23	23.5
	H_s	70	67	69.4
2	V	2.75	2.74	2.76
	E_s	138	132.5	133
	E_c (a)	1456.3	1481.8	1480.8
	E	1594	1614	1614
	T (b)	1155	1130	1135
	P (b)	160	160	160
3	V	2.75	2.74	2.76
	E	1594	1614	1614
	S	.5775	.570	.581
	T (b)	5010	5190	5050
	P (b)	780	795	793
4	V	16.5	16.45	16.58
	S	.5775	.570	.581
	E	1018	1025	1040
	T (b)	3325	3290	3370
	P (b)	87	83	83
4′	P	14.7	14.7	14.7
	S	.5775	.570	.581
	V	66	66.5	66
	H_s	614	610	625
	T (b)	2330	2325	2340
	E (b)	726	723	732
Check	on f (d)	$2.75/66 = .042$	$2.74/66.5 = .0412$	$2.76/66 = .042$
	on H_{s1} (e)	$614 \times .042 + 45 \times (1 - .042) = 69$	$610 \times .0412 + 45 \times (1 - .0412) = 68$	$625 \times .042 + 45 \times (1 - .042) = 69.4$
Work per cycle B.t.u.	$(E_3 - E_4) - (E_{s2} - E_{s1})$	462	479.5	464.5
Cycle efficiency	$\frac{\text{Work}}{(1 - f)\,H_c}$ (c)	32.0%	32.7%	31.7%
Mean effective pressure lb./in.^{2}	$\frac{\text{Work} \times 778}{(V_1 - V_2) \times 144}$	181.5	188.5	181.2

(a) E_c per lb. of air $= 1507(1 - f) + 300f$ for octane
$= 1532.8(1 - f) + 300f$ for octene

(b) Values not essential, but listed for comparison only

(c) $H_c = .0782 \times 19240 = 1504.6$ for octane
$= .0799 \times 19154 = 1530.4$ for octene

(d) f = weight fraction of the mixture existing as combustion products from previous cycles

(e) $H_{s1} = f\,H_{s4'} + (1 - f)\,H_{\text{fresh-charge}}$

The latent heat of vaporization of water so formed is

$$1057.8 \times (8 \times 18.016)/112.3 = 1359.7 \text{ B.t.u. per lb. of octene}$$

$-\Delta H$ of combustion (lower heating value) $= 1{,}277{,}900 \times 1.8/112.3 - 1359.7 = 1915.4$ B.t.u. per lb. of octene.

$$-\Delta E \text{ of combustion} = -\Delta H + \Delta(pV) \times 144/778 = -\Delta H + \Delta(NRT) = 19{,}154 + 28 = 19{,}182 \text{ B.t.u. per lb. of octene}$$

For one lb. of air as basis, with 85 percent theoretical air,

$$E = .0799 \times 19{,}182\,(1 - f) + 300f = 1532.6\,(1 - f) + 300f$$

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[1] R. L. Hershey, J. E. Eberhardt, and H. C. Hottel, *Thermodynamic Properties of Working Fluid in Internal Combustion Engines*, S.A.E. Journal, page 409, October, 1936.

[2] H. C. Hottel and J. E. Eberhardt, *A Mollier Diagram for the Internal Combustion Engine*, Chemical Reviews, December, 1937.

[3] An error exists in reference 1. The H/C ratio of the fuel was reported 2.125, instead of its actual value 2.25.

[4] A particular aviation fuel was reported to be 55 percent paraffinic, 15 percent olefinic, and 30 percent aromatic. Assume eight carbon atoms to the molecule, this composition corresponds to $(CH_{2.03})x$.

[5] Rossini and Knowlton, *Heats of Combustion of Ethylene and Propylene*, Journal of Research of the National Bureau of Standards, September, 1937.

[6] Synopsis, American Chemical Society, Rochester Meeting September, 1937.

Gifts of Books to the Institute Library

The following books have been presented to the Institute Library by Major E. E. Aldrin. The Council of the Institute thanks Major Aldrin for his generous gift of books that he has collected for many years.

Mechanical Principles of the Aeroplane, by S. BRODETSKY; 1921.

Applied Aerodynamics, by G. P. THOMSON.

Drang und Zwang, by DR. ING. AUG. FOPPL; 1920.

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(to be continued)

Helium *versus* Hydrogen for Airships

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Presented at the Rotary Wing and Lighter-than-Air Aircraft Session, Sixth Annual Meeting, I. Ae. S. January 25, 1938

Introduction

THE hydrogen fire which consumed the *Hindenburg* focused fresh attention on the factors surrounding helium as a lifting gas for airships.

Ever since 1921 all airships in the United States have used helium as the lifting gas. The problems connected with using helium have been mainly those of transporting helium from plants to desired destinations and in securing a sufficiently large volume of helium production to bring down prices. In the last ten years large supplies of helium, hitherto unknown, have been discovered so that the helium resources of the United States now appear ample to meet any prospective demands and costs of production have been very radically lowered.

Helium as a lifting gas for airships has many advantages and some disadvantages, and a complete analysis must include many factors both technical and economic. Some of the more important of these factors will be discussed briefly.

Comparative Cruising Ranges

Helium causes an appreciable reduction in cruising range of an airship, due to the fact that its "lift" is less than hydrogen and, assuming the pay load remains the same, this reduction in lift cuts down the only reducible item in the airship's loading schedule—namely the fuel.

With two airships of the same size, carrying the same useful load, the helium filled airship will have about 70 to 80 percent the cruising range of the hydrogen filled airship.

Considered in another way, if it is desired to have two airships to carry the same pay load and have the same cruising range, the helium filled airship would need to be some 15 to 25 percent larger than the hydrogen filled airship. It is the price paid for safety.

The larger airship naturally costs somewhat more to build, this increased cost being in proportion to the increase in size.

The foregoing generalizations will be apparent from consideration of the following approximate figures comparing the "lift" of helium and hydrogen. Pure helium has 8 percent less lifting power than pure hydrogen. In practice neither gas is used at 100 percent purity, so that a practical figure is probably 12 percent lower "lift" for helium, *i.e.*, 62 lbs. as against 70 lbs. "lift" per 1000 cu. ft. The fixed weights in the airship remain approximately the same in either case, so that this reduction of some 12 percent must come out of the useful load and more particularly out of the fuel portion of the useful load and may result in a reduction of some 24 percent in fuel load and in cruising range.

There are no essential changes in *design* or *construction* of the airship required for either gas. This statement must be qualified somewhat when one comes to the detailed methods adopted for using the gas, as, for example, the type of gas cells, valve arrangements, and special equipment required. The net result under this heading probably favors helium.

Gas Consumption

The consumption of helium (and hydrogen) depends in some measure on how each gas is used and in particular upon the conservation schemes that are employed.

There are diffusion losses which go on month by month whether the airship flies or not. These vary with the gas and with the type of gas container used. Helium diffuses less rapidly than hydrogen through some substances, but with other substances the reverse is true. In the case of either gas these diffusion losses are not large, probably not over 1 or 2 percent per month.

Another factor is the possibility that helium gas can be used over and over again. To accomplish this, it is necessary to repurify helium from time to time and this is generally done when its purity drops to around 85 percent. Repurification is not costly and probably would not need to be done more than once in every six months.

A case can be made that on lifting gas costs alone helium operation of airships, despite repurification costs, transportation costs, and storage costs, is about on a par with hydrogen operation. This follows because the most economical way of using helium in airships involves a somewhat modified technique of airship operation.

There are expenditures of gas which depend upon the operational practices that are used. When the airship takes off and rises to flying altitude, the gas expands and if the cells were 100 percent full at sea level some gas will pass out of the valves and be lost as the ship ascends. (This loss is roughly 3 percent for each 1000

ft. rise.) This loss can be obviated by starting with the cells say 95 percent full instead of 100 percent, thus leaving space for the gas to expand. This, of course, means that the airship must start with a 5 percent smaller load than if the cells were 100 percent full. There are several schemes for avoiding or reducing this initial loss of lift as the airship starts.

Maintaining Equilibrium

The crux of the whole matter of saving helium in airship operation lies in finding a satisfactory means for adding weight to the airship in flight so that the airship's equilibrium, or balance between "weight" and "lift" may be maintained always within reasonable limits. With a hydrogen filled airship it has been customary to maintain equilibrium by deliberately blowing off gas to reduce lift as fuel is burned and the airship tends to become "light."

The total consumption of helium through operation of the airship is largely influenced by the adequacy of the weight-adding scheme that is employed. In the ideal case no helium need be lost through valving of gas, but in actual practice valving will probably be resorted to in certain cases.

With Naval rigid airships inflated with helium and using apparatus for recovering water from engine exhaust, the consumption of helium from all causes averaged about 6 to 10 percent per month. In commercial airship operations on a regular route consumption conceivably should be less than these figures.

Economic Utilization of Helium

The economical utilization of helium in large rigid airships involves two major considerations, *viz.:*

(1) Avoiding valving helium in reaching flying altitude after take-off.

(2) Means for adding weights in flight to compensate for fuel burned.

It is of interest to review very briefly the means available for dealing with each of these.

It should be borne in mind that, once underway, moderate changes in an airship's equilibrium (balance between "lift" of gas and weights) are taken care of by flying the airship slightly inclined. It is possible to take care of about 10 percent of the gross lift aerodynamically in this fashion, but more than about 4 percent, (say eight tons for a large airship), has an appreciable effect on the margin of control available and increases fuel consumption.

Avoiding Helium Loss at Take-Off

To avoid losing helium at take-off, the following means are available:

Start with cells not quite full. Roughly 1 percent is lost for each 300 foot rise above the point where cells are 100 percent full. If flying altitude is 1200 ft., cells could be not more than 96 percent full at start. This, of course, means that the airship's static lift is reduced, and it is customary practice in the United States to employ a "rated volume" for airships which is 95 percent of the total volume in order to avoid having to reckon each take-off with less than 100 percent of the total gas capacity. To offset this partial fullness at take-off, the following means can be used:

(a) *Artificially superheat the helium gas before take-off.* This is actually done when the airship is taken rapidly from a warm shed into the colder outdoors and makes a quick take-off. Various means for creating artificial superheat have been advocated and several actually tried. Electrically applied heat, steam, and hot air have all been tried. Considerable power and heavy apparatus is required and the scheme can only be considered as a ground installation. Hot air, while uneconomical of B.t.u.'s, seems the most practical. A by-product gain is the drying out of moisture in gas cells and outer cover. Superheat of 8°F. to 10°F. can be built up in a few hours' time. Superheat of 5°F. increases gross lift about 1 percent.

(b) *Fly additional fuel (or other load) to airship via airplane* after airship has attained flying altitude and is able to carry this load dynamically.

(c) *Heavy take-off.* Small airships have taken off as much as 10 percent heavy after a run across the field. Such a maneuver seems impractical for a large airship.

(d) *Make take-off from high (telescopic) mast.* There may be a very slight advantage here over a ground level take-off, due to possible willingness to accept less static lightness at take-off.

(e) *Use vertical propeller thrust on take-off.* An upward thrust of two or three thousand pounds can be made available and might be used to assist at take-off. Once the airship has attained forward motion aerodynamic control is much more effective.

Adding Weight in Flight

The problem of adding weight in flight for a large airship of seven or eight million cu. ft. (200 tons) displacement becomes the problem of adding an average of approximately 1000 lbs. per hr. for the duration of the voyage, say for fifty hours. If this total weight can be added at such rate that the airship is never more than 1 percent (4000 lbs.) out of equilibrium from that cause, it is all that can be expected. Some of the ways that have been tried, and considered, for adding weight in flight are:

(a) *Use water recovery apparatus* to condense water vapor present in engine exhaust. In the *Akron* and *Macon* a year round weight recovery of 95 percent to 100 percent of the fuel burned was obtained. The result attained depends upon a number of factors, notably the composition of the fuel, the fuel–air ratio, and the temperatures of the exhaust and the atmosphere.

The details of the problem will vary as gasoline, safety fuel, diesel fuel, and fuel gas or hydrogen are used.

While the apparatus is heavy and somewhat of a nuisance, recovery of water from engine exhaust gases is one practical solution to the problem of adding weight to an airship during flight.

(b) *Fly additional weights on board via airplane.* The operation of airplanes to and from airships has been found to be thoroughly practical. A simple calculation will show that delivering 600 gallons of fuel every four hours would enable an airship to cruise indefinitely. The same method could be applied to pick up water from the sea and place it on board the airship at intervals during a long voyage.

(c) *Water pick-up.* Various means of picking up water from the sea or rivers have been proposed and several tried out with varying success. Some of these are: (1) an endless chain or belt carrying small buckets, sponges, or perhaps the belt itself may be made of absorbent material, (2) towing a "fish" containing a pump, and (3) a series of pumps in tandem.

(d) *Catching rain water.* This is simple and effective whenever rain is encountered.

(e) *Use of some hygroscopic material* to absorb moisture from either the engine exhaust or from the atmosphere, the water to be driven off and material used over again. Several substances, notably silica-gel, have been tried with some success.

(f) *Chemical reaction.* If the heavy substances present in the atmosphere can be captured through chemical combination of some sort, a solution to the problem may be found. Several such schemes have been proposed, but all involve heavy installations.

(g) *Recovering carbon dioxide from exhaust gas.* This has been proposed, but not yet practically applied to airships. There is a recently developed method for manufacture of CO_2 according to this general method, but it involves very heavy equipment.

(h) *Control of gas temperature in flight.* This is frequently proposed, but would be very cumbersome and at best could only bring about small and relatively temporary changes in the airship's lift.

(i) *Use of hydrogen ballonets.* If 10 to 15 percent of hydrogen is carried in ballonets inside the helium cells and this hydrogen is valved out as necessary (or better yet burned usefully), it will be unnecessary to valve out any helium. Very little, if any, increase in fire risk would be involved if the installation were properly made.

(j) *Use of helium–hydrogen mixture.* A 90:10 ratio of helium–hydrogen is non-inflammable under all conditions. If the hydrogen can be burned out catalytically to water there is a gain both from accumulating water and from decreasing the lift. This is a recent suggestion that has interesting possibilities if a satisfactory catalyst and a sufficiently light apparatus can be found.

Reducing Inflammability of Hydrogen

There is one point that should be mentioned in connection with this hydrogen-helium discussion. In Japan, Germany, the United States, and elsewhere serious attempts have been made to reduce by some means the inflammability of hydrogen and it has been found possible to reduce very appreciably the range through which hydrogen is inflammable by the addition of certain substances, notably some of the tin compounds. Such substances improve the safety of hydrogen, but being heavy they also reduce lift and in the end show no advantage over helium or over a helium–hydrogen mixture. It is possible, however, that work in this field, which is still continuing, may eventually reveal some practical means of making hydrogen safe.

Relative Operating Costs

Aside from the technical questions surrounding the use of helium there has recently been discussion as to whether helium filled airships are economically feasible. As already pointed out the costs of helium need not be greater than the hydrogen costs. With hydrogen operation as known in the past, hydrogen consumption might be ten or more times the consumption of helium under proper operating conditions. Thus helium costs ten times those of hydrogen would still prove attractive. With reasonably large scale production of helium, possible with existing plants, the costs for helium delivered into an airship on either the Atlantic or Pacific coast, including production costs, transportation costs, storage costs, and an allowance for repurification costs, may run \$6 to \$10 per thousand cubic feet. This is well within the allowable ratio to hydrogen costs.

To arrive at a complete judgment as to the relative costs of hydrogen and helium operation would require a detailed analysis and study of the mode of operation; the route covered; the ground and plant equipment, the price at which helium is available; capital investment required; etc. Although it does not reflect the advantages that will ultimately come through multiple ship operations, it has been estimated for a particular case, namely that of single ship trans-Atlantic commercial airship operation employing adequate weight recovery procedures, that the increase in total costs, including all investments and charges, for operating this single airship filled with helium instead of the somewhat smaller hydrogen airship that would carry the same pay load, might be in the order of 5 to 15 percent, assuming helium to be available at present day costs. In other words, if the all-inclusive operating costs were \$7 a mile with hydrogen, the operating costs with helium might be \$7.35 to \$8.05 per mile. The lower of these figures should be bettered as more airships were placed in service.

Institute Notes

Amendments to Constitution and By-Laws

At a meeting of the Council held on February 25, the By-Laws of the Institute were amended to conform to the experience of the first five years of the Institute. A resolution was adopted to submit several minor changes in the Constitution to the membership.

The amended drafts have been printed and sent to members so that they may know the rules and regulations under which the Institute is operated.

The principal change was the creation of a grade of membership to be known as MEMBER. There has been such a wide gap between the requirements for Associate Fellow and Technical Member that the Admissions Committee, which passes on the qualifications of applicants, found it difficult to grade some of them properly. It was believed by the Council that a restatement of the qualifications for all grades would be helpful not only to prospective members but to the Admissions Committee. MEMBERS will pay $10 a year dues and be entitled to vote and use the initials of the Institute in professional work. Technical members will continue to pay $5 a year dues, the subscription price of the Journal, but will not be entitled to vote or use the initials of the Institute. Any Technical Member may apply for regrading as a MEMBER at any time, and have his qualifications considered by the Admissions Committee.

Any MEMBER, Pilot Member, or Industrial Member may apply for election as an Associate Fellow after having been a member of the Institute for at least six months.

Only ten new Fellows may be elected in any one year. They must have been proposed by a Fellow and have been an Associate Fellow for at least one year. They are elected by secret mail ballot by the seventy present Fellows and newly elected Fellows.

These were the principal changes that were made. Some of the other minor changes were: Officers and members of the Council are not eligible for re-election for the same office; election to membership shall be by election and not by invitation as during the first year after the organization of the Institute; the Admissions Committee grades all applications for membership or regrading, except for Fellows, in place of the Council; resignations from members may be accepted only during the fiscal year during which they have paid their dues, not after bills for the ensuing year have been received; Officers will be elected before the Annual Meeting by the Council; and a code of ethics will be adopted for the guidance of members in their professional work. Other changes were made to clarify meanings and eliminate procedure no longer required.

Contribution to the Institute

The Lockheed Aircraft Corporation made a contribution of $500 to the work of the Institute and the Council expressed the appreciation of the membership.

Gifts to the Institute

Henry J. E. Reid of the Langley Memorial Laboratories of the N.A.C.A. has presented to the Institute a piece of wood from the original hangar used by the Wright brothers in their early work at Kitty Hawk. It is attractively mounted and now adds interest to the walls of the Institute offices.

Another gift was a $1/18$ scale model of a Northrop A-17A which was presented to the Institute by Jack Northrop.

A beautiful new mural for the walls of the Institute has been presented by Glenn L. Martin.

New Honorary Member

Professor George B. Pegram, Dean of Science of Columbia University, who has done so much to make the Annual Meetings and dinners of the Institute successful by securing the facilities of the Pupin Physics Laboratories and the Men's Faculty Club of Columbia University, was elected an Honorary Member of the Institute. Ministerialrat A. Baeumker, President of the Lilienthal-Gesellschaft, the highly successful aeronautical engineering society in Germany, was also elected an Honary Member by the Council.

Library

The library of the Institute is growing slowly through books sent for review in the Journal and gifts from members. The Council has decided to purchase books to provide members with an adequate reference library of aeronautical books. Members who have old aeronautical books which they wish to present to the library can be assured that such gifts will be greatly appreciated.

Directory of Aeronautical Engineering

As there is no recently published "Who's Who" in the aeronautical field, and as many requests are received for information regarding the professional record of members and others engaged in aeronautics, the Institute is compiling a Directory which will make this information available. Later, it is hoped to include all persons engaged in aeronautical engineering work, whether members or not, so that the Institute will have a complete file which will render employers and others a service of great value.

Code of Ethics

Many scientific and engineering societies establish rules of professional conduct for members. These codes state specifically what is considered to be proper activities of engineers and create high standards for the practice of their profession. A committee has been preparing such a code for the guidance of members of the Institute and will have it ready for consideration of the Council at its next meeting.

Meeting at Philadelphia

On Friday, February 18, the Philadelphia members of the Institute, in cooperation with the Aero Club of Pennsylvania, The Aviation Committee of Philadelphia, the Aircrafters, the Pylon Club, and the Aviation Country Club, held a meeting at the Franklin Institute. T. P. Wright, President of the Institute, was the guest speaker for the meeting, and E. C. Buckley, staff member of the Langley Memorial Laboratories, Langley Field, Virginia, gave a short talk and showed motion pictures taken at Langley Field. The meeting was enjoyed by the 182 persons present.

Percy Pierce, President of the Aero Club of Pennsylvania, opened the meeting by welcoming the various organizations that were present. Mr. Pierce introduced John S. Kean of the Aircrafters who expressed the pleasure their organization had at the opportunity of attending. Mr. Pierce then introduced E. Burke Wilford, acting chairman of the Philadelphia Branch and chairman of the Aviation Committee of Philadelphia.

Lester D. Gardner, Secretary of the Institute, made an announcement regarding the policy of having lectures by notable speakers for presentation at Branch meetings.

Mr. Wright briefly reviewed the 62 papers that were presented at the Annual Meeting of the Institute. He reviewed each paper briefly and as he continued down through the list, each became more interesting.

E. C. Buckley presented briefly the history and the activities of the National Advisory Committee for Aeronautics and gave running comment on the film which was recently completed of the laboratories at Langley Field. The film was somewhat changed since it was shown in New York and many agreed that the sequence was superior to that in its former presentation. The pictures were most interesting to the audience, particularly to those who have had the pleasure of attending the annual engineering conferences at Langley Field.

Those present expressed their indebtedness to the Institute for the splendid cooperation in furnishing the speakers and motion pictures; also, to George W. Lewis of the N.A.C.A. for permission to show the Langley Field pictures at the meeting. The meeting was arranged about six weeks prior to the actual date of the meeting in the office of the Secretary of the Institute in New York when E. Burke Wilford and Ralph H. McClarren visited him, showing the excellent cooperation and invaluable service that is and can be available from the Institute.

Student Branches

University of Michigan. A fifth meeting of the year of this Student Branch of the Institute was held on Thursday, January 13, in the East Engineering Building of the University. Following routine business, Lieutenant H. R. Nieman of the Naval Air Corps was introduced as the speaker of the evening. Lieutenant Nieman gave a very interesting account of his experiences at Annapolis, Pensacola, and with the Pacific Fleet. A large group attended the meeting.

University of Minnesota. A first meeting of the winter quarter was held by this Student Branch on February 1, in the Physics Auditorium of the University. Two motion pictures were shown through the courtesy of Pan American Airways; the first featuring the New York to Bermuda leg of the Transatlantic service and the second showing the features of a cruise from Miami to Rio de Janiero. Approximately 70 members were present. This Student Branch has recently begun the publishing of a small mimeographed newspaper called the I. Ae. S. News, to be published every two weeks.

University of North Carolina. Three meetings of this Student Branch were held recently, the first on January 11, the second on January 28, and the third on February 22. At the first meeting, L. R. Parkinson spoke on the Honors Night Meeting of the Institute. Captain Fred E. Davis, of Eastern Air Lines, was the guest speaker at the second meeting, and spoke on the development of the Eastern Air Lines and also on the necessity of instruments for flying. He discussed the method used for training transport pilots in instrument flying. At the third meeting, Lieutenant Courtney Shands of the U. S. Navy gave an interesting talk on "Naval Aviation and Tactics." He also spoke on the training a Naval pilot receives at Pensacola.

Necrology

Gerard F. Vultee

Gerard F. Vultee, an Associate Fellow and member of the Advisory Board of the Institute, and Vice-President and Chief Engineer of the Vultee Aircraft Division of the Aviation Manufacturing Corporation, was killed with his wife, Sylvia, in a crash of a private airplane near Flagstaff, Arizona, on January 29, 1938. He was born December 2, 1900, in New York City. A son, six months old, survives.

Gerard Vultee was very well known throughout the aircraft industry, and was highly regarded for his contributions to it. After his education at the University of California and the California Institute of Technology and a short period at the Douglas Aircraft Company, he went in 1928 to the Lockheed Aircraft Company where he shortly became Chief Engineer. Produced under his direction, the Lockheed Vega, Sirius, and Orion models were among the very first to make use of the N.A.C.A. cowling and retractable landing gears, which have since become so standard.

After two years with the Detroit Aircraft Corporation and the Ensco Aircraft Company, Mr. Vultee joined, as Chief Engineer, a new manufacturing company—The Airplane Development Corporation. Here he produced a transport airplane, the Vultee V-1A, which was outstanding in its time. Later he developed the V-11 long range attack-bomber, which now figures prominently in the air forces of several countries. About this time the name of the company was changed to the Vultee Aircraft Division of the Aviation Manufacturing Corporation and he became Vice-President as well as Chief Engineer.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps.

Aerodynamics

Recent Developments of the Theory of Turbulence. H. L. Dryden. Principal concepts which have been utilized in the formulation of theories of turbulent motion of fluids prior to 1935, and the new approach originated by G. I. Taylor in that year. Jour. Applied Mechanics, September, 1937, pages A105–A108, 1 illus., 3 equations.

Aircraft Design

Aeronautics in 1937. Noteworthy success was attained in putting the new style of aricraft on a production basis, particularly in the case of the Handley-Page Harrow bomber and the Vickers Wellesley. Progress in aircraft design during the year, and description of the following: Fairey Battle bomber, Bristol Bombay transport bomber, Bristol Blenheim bomber, DeHavilland Albatross airliner, B.A.M. survey machine, Hawker Hurricane and Henley, Westland Lysander Army cooperation monplane, Vickers Wellesley bomber, General Aircraft Company's tricycle chassis. Aircraft developments in the following aircraft companies are discussed: Boulton and Paul, Cierva Autogiro, A. V. Roe, Airspeed, Saunders-Roe and Short Brothers. Seven photographs show the Blenheim gun turret and other parts. Engineer, January 7, 1938, pages 2–5, 18, 14 illus. and 3 illus. on supp. plates.

Dive Bombing. Neither air brakes nor reversible propellers are considered to be practical solutions to the problem of preventing a modern clean airplane from reaching excessive speeds during a dive. The old-type biplane provided with a more powerful engine is recommended. Correspondence discussing editorial in December 16 issue. Flight, December 30, 1937, page 642.

The Example of the Birds. M. Tricot. The double wing of the bird is considered an excellent solution which combines the lessons of nature and the discoveries of engineers. The arrangement can be improved for rendering the aileron action. Les Ailes, October 28, 1937, page 7, 7 illus.

On Those Things Which We Have Left Undone. C. G. Grey. "On the whole air transport means risking one's life to save money or to save boredom. And that is not good enough." Mr. Grey considers that flying is becoming more dangerous and that little has been done to make airplanes land more slowly and safely. He refers to the expert as the worst bar to progress and as the one who prevents things from being done as they ought to be. He deplores the lack of development of a system he calls Radiaura, to warn one airplane of the approach of another, and discusses subsidies to civil aviation, lessons taught by the railways, the need for a study of designing airplanes for cheap and quick production as against mass production, and payload experiments. Aeroplane, January 5, 1938, page 8.

Plane Facts from the States. Important developments in aircraft design in the United States, particularly with regard to four-engined landplanes and flying boats. Features of the giant aircraft proposed or started by various companies are described, a Curtiss mystery transport plane being referred to as a four-engined transport having nose wheel and designed for substratosphere flight. Mention is made or a few details given on the following: high-altitude research, a rumored Seversky twin-engined airplane with retractable wing panels for high-speed flight, two new ships of all-wood construction (Vance Breese and Allan Lougheed's twin-engined low-wing efforts), two Menasco engines geared to a single propeller, the Luscombe method of production, Timm 840 twin-engined high-wing six-place transport with hydraulically-steerable nose wheel, and success of Fowler flaps used to increase wing loading. Editorial comment on the article points out how far behind the United States, Great Britain is in these developments. Flight, January 6, 1938, pages 12a–12d, 13, 7 illus.

Air Conditioning in the Air. F. H. Slade. Latest developments in heating and ventilation of aircraft, and trends in future designs. Amount of air to be supplied to each passenger and the oxygen necessary at 10,000 ft. are calculated and influence of type of heating on quantity of air supplied is pointed out. Design of distributing ducts is discussed in detail. Drawings include air-conditioning systems for landplanes and for flying boats, a suggested arrangement for supply of cold fresh air, rain trap, a bypass around a heat exchanger, a water-heating system, and a low-pressure steam-heating system. Advantages of electrical heating are emphasized. Aeroplane, Aeronautical Engg. Supp., December, 29, 1937, pages 813–817, 11 illus.

Airplane Performance Calculations by Means of Generalized Logarithmic Graphs. I. H. Driggs. By a simple device employing two parameters determined by the airplane dimensions power-required and power-available curves are generalized and plotted logarithmically, and a method of placing these generalized curves one over the other is found. For different altitudes the generalized power-available curve is shifted to a new position on the power-required curve. These charts are also extended to computation of range. Although the generalized power-available curve with constant-speed propeller was determined from one particular propeller test, test results with any other propeller may readily be used in constructing a new curve. Tests on one propeller are employed for the fixed-pitch generalization. S.A.E. Preprint for Meeting, January, 10–14, 1938, 19 pages, 11 illus., 5 tables, 13 equations.

Control Surface and Wing Stability Problems. A. G. Pugsley. Stiffness diagrams constructed for a typical wing indicate relative stiffness required to prevent wing-aileron flutter, wing flutter, aileron reversal, and wing divergence. By means of the diagrams the course of recent history in relation to wing-aileron flutter and aileron reversal is illustrated. Ways of avoiding the provision of increased stiffness, as usually adopted, in order to prevent flutter as well as wing divergence are pointed out. Appendices give variation of wing flutter speed with altitude and comments on wing flexural stiffness. Jour. of Royal Aeronautical Soc., November, 1937, pages 975–987 and (discussion) 987–996, 9 illus.

The Hull-less Flying-Boat. H. R. Cox and L. P. Coombes. The swept-back tailless hull-less flying boat proposed would have floats retractable to form wing tips, a retractable step, fins and rudders near the wing tips, and combined ailerons and elevators. Comparative weight analysis of this type and of the conventional flying boat is given. Possibility of building a seagoing flying wing is considered in detail. Form of wing able to take off from water, general biplane and monoplane designs, as well as the tailless design are discussed. Results of model tests. Paper published with permission of the British Air Ministry. Aeroplane, December 1, 1937, pages 677–680, 7 illus., 2 tables.

Limit to Speed Predicted. Major A. W. Stevens. Possible speed limit at 408 m.p.h. is predicted, and altitude limits for aircraft operation are referred to, especially the difficulties in designing propellers for operation in the stratosphere. Brief quotation from Kiwanis Club paper as quoted in the New York Times. U.S. Air Services, January, 1938, page 23.

Lindbergh Writes a Letter. Aircraft having a payload capacity of 25,000 lb., stateroom and other accommodations for at least 100 passengers, crew accommodations for 16, and range of 5000 miles in still air at cruising speeds of not less than 200 m.p.h. at sea level. These conditions are imposed in Lindbergh's invitation to aircraft manufacturers for bids on a new Pan American aircraft. Special consideration will be given to designs permitting operation at 20,000 ft. altitude or higher with interior cabin pressures equivalent to 8,000 ft. altitude. A few other details from specifications accompanying the letter are given. Aviation, January, 1938, pages 51, 66, 1 illus.

General specifications and manufacturers invited to submit proposals. Western Flying, January, 1938, pages 27–28.

Taxying Bumps. A. E. Parker. Comments on Mr. Corner's criticism of the author's recent article. The author revises Mr. Corner's calculations for finding the value of maximum load due to taxying bumps, taking into account the effect of damping and reducing the length of travel. Flight, Aircraft Engr. Sup., December 30, 1937, pages 40–41, 2 equations.

Wilford Gyroplane. E. Daland. Calculated performance characteristics are given for the Curtiss Wright 19R monoplane and for three gyroplane modifications of it, namely as a standard Wilford gyroplane with wings and a rigid feathering rotor, as a wingless-type gyroplane with the same feathering rotor designed to carry all the load at all speeds, and as a gyroplane with fixed wing but incorporating arrangements so that the rotor may be stopped in flight. Aviation, January, 1938, page 42, 3 illus., 1 table.

Wing Loading. H. F. Vessey. Concluding installment of Royal Aeronautical Society paper. Flight, Aircraft Engr. Supp., December 30, 1937, pages 35–40, 5 illus.

The Mystery of Oblique Attack. Wind-tunnel test results at Chailais Meudon carried out on the propulsive system invented by M. Budig. Under certain conditions of oblique attack of the profile with respect to the wind, M. Rebuffet found a negative drag. At an angle of 45° a model wing of 5 mq. produced a propulsive force of nearly 40 kilos. Variation of pressure at an oblique attack of 0° to 45° is shown. Les Ailes, December 2, 1937, page 8, 8 illus.

Technical Progress in 1937. T. James. British military types; progress abroad as shown at the Belgian, Zürich, and Milan shows; the Focke-Wulf helicopter; the Everel single-bladed propeller; the Nagler Helicogyro; high-altitude record and transatlantic experimental flights; refueling in the air; lack of catapult developments; and shadow factories. Aeroplane, Aeronautical Engg. Supp., January 5, 1938, pages 16–18, 2 illus.

Stress Analysis and Structures

The Calculation of Maximum Deflection, Moment, and Shear for Uniformly Loaded Rectangular Plate with Clamped Edges. I. A. Wojtaszak. Results of calculations for several ratios of the sides of the plate, using Hencky's equations. Curves are drawn with the coefficients, used in defining these maximum quantities, as ordinates and the ratios of the sides of the plate as abscissas. Jour. Applied Mechanics, December, 1937, pages A173–A176, 1 illus., 2 tables, 24 equations.

Recent Research in Elasticity. J. N. Goodier. Stability; stress analysis in two dimensions; photoelasticity; torsion and flexure; flexure of plates; thermal stresses; impact; and frameworks. Review of literature. Jour. Applied Mechanics, December, 1937, pages A179–A182.

The Stability of a Clamped Elliptic Plate Under Uniform Compression. S. Voinovsky-Krieger. Energy criterion of stability, investigated by G. N. Bryan and S. Timoshenko, is applied to plates bounded curvilinearly, and the case of the elliptic plate is given as an illustration. Jour. Applied Mechanics, December, 1937, pages A177–A178, 7 equations.

The Design of Multispar Wings. W. Billewicz. Parts of W. F. Kisielew's paper on the design of multispar wings, and the author's original work connected with experimental research at the Polytechnic Institute of Warsaw are given. Calculations cover wings of infinite span, shearing stresses in the section, wings with finite span and the fixed end section. Jour. Royal Aeronautical Soc., November, 1937, pages 1041–1065, 11 illus., 4 tables, 23 equations.

Torsion of Rectangular Tubes. W. Hovgaard. Experiments with rectangular mild-steel tubes undertaken to test the correctness of the theory of R. Bredt, based on hydrodynamical analogy. Observed angles of torsion were found to be in fair agreement with theory but shearing stresses on the external surface were much higher and those on the internal surface much lower than theoretical stresses. Theory does not give a true picture of stress distribution after plastic flow has occurred at re-entrant corners, and as this may happen very early, dependent on fillet radius, the theory may lead to dangerous overestimate of strength. Jour. Applied Mechanics, September, 1937, pages A131–A135, 10 illus., 1 table, 8 equations.

Aircraft

Speed Records. Significance of the speed records recently made with German and Italian aircraft, and what should be done by the French aircraft designers in order to attain the technique revealed by these records. Opinions of A. Brunet, L. Bossoutrot, C. Waseige, M. Riffard, M. Doret and R. Fonck. Les Ailes, December 23, 1937, page 6.

BELGIUM

Renard R-36 Pursuit. A. Frachet. Metal monoplane has a fineness of 16 and is equipped with a Hispano-Suiza 910-hp. motor cannon, the cannon and four machine guns firing 100 projectiles per second.

The airplane should fly at more than 500 km./hr. Long description, characteristics, performance. Les Ailes, November 25, 1937, page 9, 3 illus., 2 tables.

FRANCE

Airplanes in Test. Marcel Bloch 210 (two Renault 14-Fas radial aircooled engines each developing 1000 hp. at 2000 r.p.m. at 4000 meters). Le0-45 high-speed bomber. Levasseur marine airplane (Gnôme Rhône K-9 750-hp. engine). Morane-Saulnier 430 two-seater (Salmson 390-hp. engine). Brief references only to these military airplanes. Les Ailes, January 6, 1938, page 5.

Another New Type for Air France. The new prototype Couzinet 10 has registered a cruising speed of 208 m.p.h. at 74 per cent power. It has Hispano Suiza 9-V engines of 650 hp. each. Brief reference. Flight, January 13, 1938, page 44.

Air and Water. Air France has ordered the first of a number of Latécoère 58-ton flying boats for use on its transatlantic services. Airplane will be a high-wing monoplane and its six 1500-hp. engines will give a cruising speed of 215 m.p.h. and top speed of 260 m.p.h. Brief reference. Engineer, December 17, 1937, page 685.

Airplanes in Test. Amiot 340 bomber (two Gnôme Rhône 14-No. engines giving 1900 hp.). Marcel-Bloch 150 pursuit (Gnôme Rhône 950-hp. engine). Hanriot H-220 three-seater light fighter (two Mars 650-hp. engines). Loire-Nieuport 161 No. 2 (Hispano-Suiza 12 Ycrs 850-hp. "moteur canon"). Potez 56 T. 3 observation (two 185-hp. Potez engines). Marcel-Bloch 133, new version of the B.C.R. Bloch 131 (two Hispano-Suiza 14-A engines). Morane-Soulnier 430 trainer (Salmson 390-hp. engine). Brief references only to these airplanes in test. Les Ailes, December 23, 1937, page 9.

LeO-45 High-Speed Bomber. A. Frachet. Bomber is said to be the most remarkable French offensive prototype. With a considerable load of projectiles and powered with two Hispano-Suiza 1100-hp. engines, the airplane has a higher speed than many of the French pursuits. Estimated top speed at 4000 meters is 483 km./hr. Long description, characteristics, and estimated performance. Les Ailes, December 2, 1937, page 9, 6 illus., 2 tables.

LeO H-246 Commercial Flying Boat. A. Frachet. Monoplane of mixed construction (four Hispano-Suiza 12-Xirs 720-hp. engines) will be capable of transporting 26 passengers, a crew of 4 and 400 kg. of freight over 1500 km. at a maximum speed of 335 km./hr. Long description. Les Ailes, October 28, 1937, pages 5–6, 3 illus., 2 tables.

Potez 661-662 Four-Engined Twins. A. Frachet. These two new French prototypes should be capable of transporting 12 passengers over 1000 km. The P-661 should attain 326 km./hr. with four Renault 220-hp. engines. The P-662 having a reinforced structure will be powered by four Gnôme Rhône 680-hp. engines and should make 470 km./hr. Long description, characteristics, performances. Les Ailes, January 6, 1938, page 9, 2 illus., 2 tables.

The Presentation at Villacoublay. Caudron-Renault, Morane-Saulnier 405, Nieuport 161 and Bloch 150 pursuits; the Bloch 133 and 131, Potez 63–1, Lioré 45 and Farman 222–2 bombers; the Potez 63–1 pursuit command; the Potez 56–6 observation; and the Romano 82 and Hanriot 230 trainers. Table shows engines, total weight, speed, altitude, and range of these airplanes which were recently exhibited at Villacoublay. Designs are briefly discussed. Les Ailes, December 2, 1937, page 10.

Records. Latécoère 521 "Lieutenant-de-Vaisseau-Paris has beaten five world records: 211 km./hr. over 1000 km. with 10,000 kg., 180 km./hr. over 1000 km. with 15,000 kg., and 18 tons at 2600 meters in 45 minutes. Description of flights. Les Ailes, January 6, 1938, page 5, 1 illus.

Two French Record-Breakers. World's altitude record for single seaters of less than 2-liters engine capacity was broken when M. Tonya reached a height of 16,240 ft. in a plane of his own design powered with a 40-hp. Train 4T. engine. With a copilot he reached the height of 22,965 ft. in a two-seater L'Aile Volante A.V. 10 powered with a special 75-hp. Pobjoy. Photographs only. Flight, January 6, 1938, page 12, 2 illus.

Two More Records for the "Lieutenant." Latécoère H. 521 (six 650-hp. Hispanos) has beaten, by the large margin of 8000 kg., the previous record of 10,000 kg. for the heavy load carried by a flying boat at an altitude of 6000 ft. This was formerly held by by the Italian Cant 508. The H.521 has also established a new record by carrying 15,000 kg. at 9000 ft. Brief ref. Flight, January 6, 1938, page 18.

GERMANY

Control of the F.W.-61 Helicopter. All the maneuvers of the Focke-Wulf F.W.61 are obtained by means of the main throttle and simultaneous or differential inclination of the hubs of the two rotors. Rotor blades are articulated to a universal joint and automatically change their incidence for a glide when the engine has been shut off. Description of performance and controls. Les Ailes, December 23, 1937, page 5, 1 illus.

Following It Up. World records made in November with airplanes powered by Daimler Benz DB-600 engines. Brief note. Aeroplane, December 8, 1937, page 717.

Meant for Business. New Dornier Do.24 deep-sea flying boat developed for the East Indies station of the Netherland's Navy has successfully passed seaworthiness tests in extremely rough weather. The boat has a swept-up stern carrying a two-finned adjustable tailplane, a combination of split and slotted flaps, and three gun turrets, one located in the extreme stern. Three 700/900-hp. motors are mounted in the leading edge of the wing. Top speed is from 315 to 340 km./hr., according to motors, and range is over 3500 km. Short description. Aeroplane, January 5, 1938, pages 19,4–5, 5 illus.

Weight-Putting. Germany gained another International Class Record for airplanes on November 22 when Flugkapitan Nitschke and Flugzeugfuehrer Dieterle flew a twin-motored Heinkel (two Daimler-Benz liquid-cooled engines) with a load of 1000 kg. at a speed of 504 km./hr. over a 1000-km. course. Earlier in the same day General Biseo and B. Mussolini had set up a record of 269.1 m.p.h. over the same distance with a load of 2000 kg. Brief note and photographs of the latest Heinkel of the record-breaking type with 950-hp. Daimler-Benz motors. Aeroplane, December 1, 1937, page 663, 2 illus.

GREAT BRITAIN

Fruits of 1937. 1937 has been a production rather than prototype year, particularly on the military side, although some outstanding new aircraft have made their debut. Gloster Gladiators issued to the R.A.F. are the most popular machines ever adopted. As the year closes the first Supermarine Spitfire and Hawker Hurricanes are coming through, Handley Page are passing on to Hampden medium bombers, Vickers are building special Wellesleys for the Long-Range Flight, and work is under way at Short and Harland works on Bombay bomber transports and a version of the Hampden with Dagger E.108 engines. Progress in military and civil aircraft and in aircraft engines. Flight, December 30, 1937, pages 638–641, 11 illus.

High Performance in Miniature. Chilton monoplane cruising at 100 m.p.h. on a 32–b.hp. Ford engine with dual ignition. Flying characteristics. Flight, December 30, 1937, page 649, 2 illus., 1 table.

To Get Records for England. Performance data on the Wellesley and conditions which it would have to meet in order to obtain the world's distance record for England. Short note. Aeroplane, December 1, 1937, page 663.

Quarter of a Century. Some outstanding Avro airplanes, and an account of the achievements of A. V. Roe and Company in the last 25 years.

In a second article entitled "A Pioneer Remembers," Sir Alliott Verdon-Roe gives a review of his thirty years of aircraft building. Flight, January 13, 1938, pages 30–33 and 36a–36d, 16 illus.

HOLLAND

Perseus Performance. No power figures for the fully-supercharged Bristol Perseus sleeve-valve engine have been issued in England. Some estimated performance data are given which were supplied by Fokker on the G.1 twin-engined fighter-attack monoplane powered with two Bristol Mercury VIIIs (maximum speed 288.7 m.p.h. at 16,070 ft.) and with two Bristol Perseus fully-supercharged engines (301 m.p.h. at 14,760 ft.). The Perseus engine, in medium-supercharged form, is already in service with the R.A.F. in the Vildebeest IV torpedo bombers. The Blackburn Skua dive bomber fleet fighter is likely to have a fully blown Perseus, and the later editions of the Lysander will mount a medium-supercharged version. Flight, January 13, 1938, page 40, 1 table.

ITALY

The Italians Raise the Distance Record for Seaplanes to 7000 Km. Stoppani's record flight in the Cant Z–506 and the new record made with the Savoia Marchetti S-74 (four Alfa Romeo 162 R.C.-34) at an average speed of 322 km./hr. over 1000 km. with a 10-ton load. Details of flights and equipment. Les Ailes, January 6, 1938, page 6.

Non-Stoppani. World's Distance Record for Seaplanes was acquired by M. Stoppani who covered more than 7000 km. (4349.8 miles) non-stop in a Cant Z.506B bomber twin-float seaplane powered with three 770-hp. Alfa-Romeo 126 RC.34 radials. A second record was made with three others in the seaplane across the Atlantic at an average speed of 266.5 km/hr. (165.5 m.p.h.).

A Savoia Marchetti S.74 transport (four 770-hp. Alfa-Romeo 126 RC.34 engines) piloted by G. Tesei and L. Rosci beat the International Class record for airplanes over 1000-km. course with 10 tons of useful load at an average speed of 322 km./hr. (200 m.p.h.).

A Savoia Marchetti S.79 (three 610-hp. Piaggio P.IX R.C.-40 engines) piloted by A. Vacula and P. de Ambrosis with two mechanics, improved the International Class Records for Speed over a distance of 2000 meters without load and with a load of 500, 1000, and 2000 kg, at an average speed of 428.296 km./hr. (266 m.p.h.). Aeroplane, January 5, 1938, page 3, 1 illus.

A Promising Line of Development. Beltrame Colibri tail-first pusher airplane takes off fully-loaded on 18 hp. It has a top speed of 160 km./hr. and a better ratio of loaded-to-empty weight than the conventional airplane. There is no rudder and directional control is obtained by tilting the nose elevator to one side or the other. Description. Aeroplane, December 1, 1937, pages 680–681, 3 illus., 1 table.

U. S. A.

America Misses It. Photograph of "one of the latest Lockheed monoplane fighters . . . . if instead of boring holes in the flap, the makers had cut a series of slits and then turned over the metal from the slit so that, with the uncut piece, it might form a rough sort of aerofoil, the flap might thus give considerable lift within certain angles instead of merely causing drag." Airplane belonging to the Attack Group, U. S. Army Air Corps winning the Columbia trophy. Aeroplane, December 8, 1937, page 689, 1 illus.

An American "Wet." "Curtiss P-37 single-seater pursuit monoplane with 1000-hp. Allison liquid-cooled engine, the first American machine of its type to be fitted with anything but a radial for some years. It seems that the exhaust-driven blower is housed more carefully than in previous installations of the Allison." Photograph only. Flight, December 30, 1937, page 651, 1 illus.

Few details and references to Army contracts for thirteen. Aero Digest, January, 1938, page 90, 1 illus. U.S. Air Services, January, 1938, page 23, 1 illus.

Australian News. "The first NA-16 to be seen in Australia did not excite much comment, and pilots who have handled it are not impressed by its performance in bad weather, when it is apt to do many things which it should not. The NA-16s to be built in Australia will really be NA-33s. Brief note. Aeroplane, December 8, 1937, page 711.

A Baltimore Bolshevik. "A four-motored Martin Flying-Boat, built bigger than the earlier Martin Clippers, for the Government of the U. S. S. R. It is of a fairly antique type and need cause no worry at Rochester (Kent)." Photographs of flying boat under construction. Aeroplane, December 8, 1937, page 690, 2 illus.

Consolidated's Trans-Oceanic Project. Projected 54-passenger flying boat of 110,000 lb. gross weight, having all the comforts of a luxury liner. Four engines will provide 6000 hp. at 2300 r.p.m. for take-off and top speed will be 226 m.p.h. at 10,000 ft. Range will be 6000 miles with 10,000 lb. payload, and 3000 miles with 30,000 lb. payload. Aviation, January, 1938, pages 24–25, 4 illus., 1 table.

Consolidated XPB2Y-1. Latest Consolidated contribution to the Navy's aircraft fleet, namely, the high-performance XPB2Y-1, 4-engined patrol bomber flying boat for long-range operation. Few details referring briefly to retractable navigation turret behind the wing, independent generating system, beaching gear that can be quickly stowed in the interior of the fuselage, and workshop for maintenance work in flight. Aviation, January, 1938, pages 30–31, 5 illus. Western Flying, January, 1938, page 30, 1 illus.

Brief note. Aero Digest, January, 1938, page 90, 1 illus. U.S. Air Services, January, 1938, page 34.

The Explorer. New Abrams monoplane designed specifically for aerial photography and mapping has exceptional forward and downward vision, rapid climb to high altitudes, pusher propeller, tricycle landing gear, and a hermetically-sealed mapping porthole built into the floor of the gondola which is located close to the ground. A "door within the door" permits the camera man to take photographs at an oblique and forward angle without opening the outer door. Cabin is airtight for supercharging. Airplane is powered by a Wright J-6-9 E 330-hp. engine and has a maximum speed of 185 m.p.h. and cruising range of 1200 miles. Aviation, January, 1938, page 41, 3 illus. 3 tables.

Martin's Ocean Transport. Work will start soon on a new transport which will have a wing spread of 188 ft., the largest of any airplane ever built in this country. Transport will carry 100 passengers by day or 66 by night and be able to fly the Pacific in a single hop or make a round-trip nonstop flight to Europe. Brief reference. U.S. Air Services, January, 1938, page 35.

Martin to Build 21 Giant Patrol Bombers for U.S. Navy. Specifications for the twin-engined flying boats call for a cruising range and bomb load unequaled by any other plane of this type. Brief reference only. First flying boat will be ready for testing early this year. U.S. Air Services, January, 1938, page 32.

The Arrowbile. W. D. Waterman. Development work which went into the design of the flying automobile. Airplane has tricycle landing gear, pusher propelier, wings detachable in three minutes, a 115-m.p.h. maximum speed and 45-m.p.h. landing speed. Long abstract S.A.E. paper. Automotive Industries, January 22, 1938, pages 106–109, 119, 120, 129, 5 illus.

New Plane for Photographic Mapping in the Stratosphere. T. Abrams. In the Explorer strato-plane the pilot's compartment is located in front in a glass-enclosed gondola to give the pilot the forward and downward visibility necessary for photographic mapping. A door within a door allows the cameraman to sit in his regular seat and without opening the main outer door take pictures at an oblique and forward angle. A special hermetically sealed mapping porthole with special camera mount is located in the gondola floor. Supercharging of the cabin is provided. Powered with the Wright J-6-9-E 330-hp. supercharged engine driving a pusher propeller, the airplane is expected to attain a maximum speed of over 200 m.p.h. at 21,000 ft. Long description. Photogrammetric Engg., October-November-December, 1937, pages 1–4, 2 illus., 3 tables

A New Seversky for the Executive. Three-place cabin plane is rated at 340 m.p.h. at 18,000 ft. altitude when equipped with Pratt & Whitney twin-row Wasp 1200-hp. engine, and has a range of 2790 miles. Specifications and performance. Aviation, January, 1938, page 37, 2 illus., 1 table.

Propeller Driven. Three views of the Bell Airacuda with the comment that it ought to be good but could have been made faster without extra cost. Aeroplane, December 1, 1937, pages 662, 664, 4 illus.

Standard and Deluxe Fairchild 24 for 1938. Four-place high-wing monoplane which will replace the three-seater. Powered with a 145-hp. Warner Super-Scarab engine, the standard type has a maximum speed of 138 m.p.h. and cruising range of 530 miles. Long description and performance. Aero Digest, January, 1938, pages 46,48, 3 illus. Western Flying, January 1938, page 29, 2 illus., 1 table.

Vultee Attack Bomber V-11GB. Military airplane may be equipped as an attack plane, light bomber, or ambulance airplane, or for use on reconnaissance and photographic missions. Equipped with a Wright Cyclone GR-1820-G2 850-hp. engine and Hamilton Standard constant-speed propeller, the bomber has a top speed of 237 m.p.h. and maximum range of 2380 miles with military load. Description of construction, and specifications for the airplane equipped as a medium-range attack plane and as a long-range bomber, respectively. Aviation, January, 1938, pages 32–33, 71, 8 illus., 2 tables.

America Cleans Up. "Curtiss P-36 single-seater ordered in quantity for the U.S. Army Air Corps. It is a clean design to the modern formula, but the undercarriage, which twists when retracting (as on the Miles Kestrel Trainer), gives rise to two excrescences." Comparison of two Great Lakes dive bombers, and a Curtiss A–18 twin-Cyclone attack "a shapely two-seater which carries a big armament load." Photographs only. Flight, January, 13, 1938, page 36f, 4 illus.

Aircraft Accessories

New Accessories for Aeroplanes. Lockheed hydraulic constant-speed-propeller control, Smith flap-position indicator, Dowty hydraulic jacks for medium bombers, Serck combined radiator and oil cooler for a high-speed two seater, and Timken bearing for the rocker arm of an aircraft engine. Photographs and brief references. Aeroplane, December 29, 1937, page 826, 5 illus.

Cleats for Tires. General Streamline low-pressure tire with steel cleats embedded in the tread. Photograph only referring to Air Corps experiments. Aviation, January, 1938, page 23, 2 illus. Scientific Am., January, 1938, pages 34, 36, 1 illus.

Aircraft Accidents

Australia's Latest Farce. Inquiry into the airworthiness of Hawker Demons following nine accidents in Australia in more than a week. Enumeration of accidents, and editorial comment. Aeroplane, January 5, 1938, page 4.

Recent accidents to the Demons are said to have been due almost entirely to inexperienced piloting or to poor ground maintenance. Brief reference. Flight, January 13, 1938, page 40.

Air Transportation

Air Transport in 1937. F. D. Bradbrooke. Achievements of Imperial and British Airways and progress in air transport in Australia, Canada, South Africa, and Europe. Aeroplane, January 5, 1938, pages 21–23, 2 illus.

Transport Comparisons. R. A. E. Luard. First issue—Comparative table of efficiency giving data on British and American transports for use of the airline operator in selecting his fleet. Some new ideas in the economics of air transport are presented.

Second issue—Table shows figures for the D.H. 89A, Lockheed 12A, D.H. 86A (with Series I motors) and Lockheed Electra 10A. Discussion of previous article by R. A. E. Luard. Flight, January 6 and 13, 1938, pages 16–18 and 45, 5 illus.

Airlines Need "Star Routes." T. P. Hay. Three proposals for the development of feeder airlines to serve the smaller communities and to bring passengers to the faster transcontinental air services. Aero Digest, January, 1938, pages 24, 26, 3 illus.

British Aeroplanes on the World's Air Routes. British transports operating in Canada, Australia, India, Africa, Palestine, Europe, and South America. Aeroplane, December 29, 1937, pages 818–819, 2 illus.

Propellers

Flying the Single-Blade Propeller. Performance of the Everel propeller in the Cessna and Taylor Cub airplanes. Aeroplane, January 5, 1938, page 19, 1 table.

Aircraft Instruments and Navigation

Automatic Controlled Blind Landings. Capt. G. V. Holloman. Flight tests were made at the Materiel Division to determine the control required for obtaining "slow cruise" and desirable glide, or "let-down" conditions. Results are described. Regardless of type of airplane and altitude, constant values were obtained for difference in airspeed between level attitude position during "let down" and airspeed at stall, as well as for decrease in stalling speed from rated value. The author shows how the "slow cruise" and "let-down" conditions may be established by manual control of the automatic pilot and through use of the automatically controlled automatic pilot and allied automatic equipment. He explains the operation of the radio equipment of the standard Army instrument landing system. S.A.E. Preprint for Meeting, January, 10–14, 1938, 7 pages.

More Blind Approach Assistance. Sperry airport orientator being tested by the Bureau of Air Commerce is intended to give the pilot a properly orientated picture of the airport which is being approached in bad visibility. Orientator in which a circular chart may be quickly fitted for any particular airport, is directly connected to the disk member on top of a directional gyro. Few criticisms from the British point of view. Flight, December 30, 1937, page 646, 1 illus.

Description. Aero Digest, January, 1938, pages 54, 56, 7 illus.

AIR NAVIGATION

Finding Your Way in the Air. Lt. Comdr. P. V. H. Weems. Method of solution by line of position book, and celestial navigation equipment required for solving the astronomical triangle. Continued. Aviation, January, 1938, pages 28–29, 5 illus.

Airport Equipment

Aerodrome Equipment. Eclair doors for hangers, Thompson three-wheel aircraft refueling equipment, Air-foam trailers for protection against fire, and Chance mobile floodlight unit made for R.A.F. airports. Brief notes. Aeroplane, December 29, 1937, page 825, 4 illus.

Rolling It Down. Equipment developed by L. D. Hammond and used at Minneapolis Muncipal Airport for handling the snow problem. Aviation, January, 1938, pages 22–23, 3 illus.

The Singapore Airport. British Empire's greatest overseas air base constructed both as a land and sea station. Hangars, slipway and wharf, lighting system, and control tower. Engineer, September 17, 1937, pages 316–317, 6 illus.

Electrical Equipment

Developments in the Electrical Industry During 1937. G. Bartlett. Outstanding developments in aviation are considered briefly and references are made to new d-c Selsyns aviation instruments, high-frequency alternator to provide accessory power on large aircraft and driven by an exhaust-gas turbine, new and better alloys for exhaust-gas driven superchargers, larger sizes of impellers and diffusers developed for geared superchargers, and special forms of cabin superchargers for military and commercial aircraft. General Electric Rev., January, 1938, page 32, 1 illus.

Ice Eliminaton Equipment

Ice Prevention in This Country. R. S. Findley. French tests on the thermoelectric anti-icing device known as the "Proceded Rideau-Ducret" seem to prove that a 25-hp. generator will generate enough heat to keep ice from forming on the leading edge of the airplane over an area of 10 sq. meters, the plane being powered with 1000-hp. and flying at 300 km./hr. in a temperature of minus 3° or 4° C. Brief reference to this device and details of the new deicing equipment installed on TWA transports including antenna deicing means. U.S. Air Services, January, 1938, page 38.

Miscellaneous Equipment

Modern Oxygen Equipment. Avimo oxygen equipment. Curve of supply in relation to height is absolutely straight from 15,000 to 40,000 ft. or higher if necessary. Opening of the delivery valve is controlled by a cam which can be designed to alter the supply to any other desired rate. A device is provided whereby the pilot can test proper working of equipment before taking off. Short description. Aeroplane, December 8, 1937, page 715, 1 illus.

Spot- and Seam-Welded Aluminum Tanks for Aircraft. F. V. Hartman. Function of baffles, baffle design and construction, advantages and disadvantages of single-pan type baffles, fastening the head to the skin sheet, thickness of material that can be welded, and comparison of mechanical properties of two aluminum alloys used for tanks, namely 3S and 52S alloys. Mechanical Engg., December, 1937, pages 925–929, 9 illus., 1 table.

Equipment for High-Altitude Flight. M. Victor. Oxygen equipment for pilots flying airplanes at high altitudes. Les Ailes, November 25, 1937, page 8, 6 illus.

Fatigue Life of Tapered Roller Bearings. W. O. Clinedinst. General fatigue expression and series of formulas covering contact stresses, the general equation being applied to individual parts of the bearing. Mathematical expressions for radial and thrust capacities and equivalent loading formulas are developed for operating conditions. Effect of materials, surface finishes, and manufacturing tolerances on bearing life are discussed. Jour. Applied Mechanics, December, 1937, pages A143–A150, 14 illus., 25 equations.

One-Piece Asbestos Suit Gives Added Protection at Fires. Johns-Manville suit having shoes and garment all in one piece, a safety hook attached to belt and a heat-proof glass suspended from the visor of the hat. Brief note. Oil & Gas Jour., January 20, 1938, page 157, 1 illus.

Aerial Photography and Mapping

The Construction of Map Projections by Modern Methods. R. E. Ask. Projection ruling machine developed by the Coast and Geodetic Survey. Construction, operation, and results obtained. Photogrammetric Engg., October–November–December, 1937, pages 7–12, 2 illus., 3 tables.

Dimensional Changes in Aerial Photographic Films and Papers. R. Davis and E. J. Stovall, Bureau of Standards. Shrinkage of aero films as a function of relative humidity, film shrinkage due to processing and accelerated aging, and shrinkage of photographic papers due to processing are considered. Experiments, equipment, test results, and recommendations are covered in detail. Optical extensometer described is based on the mechanical principles of the pin gage which was designed for measuring paper shrinkage. Study of acetate film for use in aerial cameras is recommended. Photogrammetric Engg., July–August–September, 1937, pages 35–53, 20 illus., 6 tables.

Fairchild Solar Navigator. L. T. Eliel. Sun compass described is mounted in the dome of the airplane and set up exactly like an astronomical telescope, its axis pointing north so that a clock rotating a mirror on an axis parallel to the axis of the earth follows the sun. Mirror is adjustable for varying declination of the sun and reflects sunlight through a lens to two photoelectric cells. When compass points exactly north no light falls on the cells but the slightest deflection is registered on a galvanometer on the instrument board. A very sensitive level bubble is mounted beneath the galvanometer. Description of sun compass, view finder, drift sight, and setting up and use of the equipment in operation. Photogrammetric Engg., October–November–December, 1937, pages 30–35, 4 illus.

A Practical Method of Tilt Determination for Multilens Aerial Photographs. S. H. Birdseye. Difficulties encountered in map compilation on the El Salvador-Guatemala boundary line, their solution by a new method devised for tip analysis, and the Prieto device. The device graphically determines the corrections to be applied for list and tip without recourse to calculations or tabulations with the exception of one diagram for determination of McAdam's "mean band" adjustment to the list corrections. Device is compared with Lt. Col. J. W. Bagley's aerial photograph calculator.

The tilt-finding device used by the El Salvador-Guatamela Boundary Commission to determine the list and tip components of tilted mutiple-lens photographs is described in detail by the inventor A. G. Prieto in a second article. Photogrammetric Engg., October–November–December, 1937, pages 22–24 and 24–28, 4 illus.

Progress Report of Committee on Control for Photo-Mapping. Beltsville, Maryland, test project for horizontal control of photographic mapping by different methods in gently rolling terrain. Tests were made on different kinds of aerial photographs and on the several methods used in compiling maps from them in order to decide which method will best fit requirements in mapping that type of terrain. Photogrammetric Engg., July–August–September, 1937, pages 54–57, 1 illus.

Radial Plotting by Principal Point Rays. W. Scholla. Theoretical phases of the method of radial plotting for constructing planimetric maps from "vertical" aerial photographs. Photogrammetric Engg., July–August–September, 1937, pages 27–34, 8 illus.

The Radial-Stereoplotter. E. L. M. Burns and R. H. Field. Machine developed by the Associate Research Committee on Surveys, Canada, for plotting from air photographs, by the radial line method. Principles involved in design of the machine, its construction, and method of plotting control are described in detail. Azimuth and scale errors, effect of tilt in a flat country, and tilt and elevation differences are discussed with methods for eliminating them, or for correcting the plot. From Canadian Journal of Research. Photogrammetric Engg., October–November–December, 1937, pages 48–62, 10 illus.

Shutters for Aerial Photography. F. W. Lutz and L. W. Doyle. Requirements of a good aerial camera shutter are considered and various types of focal-plane shutter and shutters operating at or near the optical center of the lens are described. Shutter-speed testing machines, and a special modification for testing multi-lens synchronized electric shutters are discussed. Photogrammetric Engg., July–August–September, 1937, pages 1–6, 5 illus.

Standard Specifications for Aerial Photography for General Map Work and Land Studies. Surveys; vertical negatives; contact prints; ratioed prints and general enlargements; oblique photographs; and special conditions. Photogrammetric Engg., July–August–September, 1937, pages 59–75.

A Timber Survey Controlled by Aerial Photographs. J. G. Kelley. Method described was dependent upon a radial-templet compilation on a 1:15, 840 scale. Photogrammetric Engg., October–November–December, 1937, pages 4–5.

Abstracts of Articles of Interest to Photogrammetrists. Very brief abstracts. Photogrammetric Engg., October–November–December, 1937, page 29.

Materials

Bright Annealing of Seamless Steel Aircraft Tubing. H. R. Lewis. Methods employed at the Ohio Seamless Tube Company. Metals & Alloys, December, 1937, pages 331–334, 5 illus.

High Strength Light Alloys. E. R. Gadd, Chief Metallurgist, Aero-Engine Div., Bristol Aeroplane Co. Improved alloys and production methods, especially in aeronautical construction. Introduction of heavy presses; applications of magnesium alloys; magnesium alloys in engine construction (new casting alloy containing tin and silver); wrought magnesium alloys; magnesium alloy pistons; aluminum alloys in engine construction; internal stress in heat-treated alloys; mechanical properties of light alloys for use in aircraft construction at atmospheric temperature; wrought alloys for aircraft construction; aluminum base alloys as bearing materials; bending problem; and developments in beryllium alloys. Metal Industry, January 7, 1938, pages 5–10, 5 illus., 2 tables.

Quality Control of Aluminum Alloy Aircraft Castings. K. R. Van Horn and H. J. Heath. S.A.E. Jour. (Trans.), January, 1938, pages 4–12, 13 illus.

Paints and Varnishes in Aviation. Part II. L. Dacy. Protection of wooden parts by means of oil varnishes , cellulose lacquers and bakelite, tar and synthetic resin oil varnishes. Brief abstract from Peintures-Pigments-Vernis, 1937, 14, No. 1.

Also brief abstracts entitled: "Application of Aircraft Lacquering." "Aluminum in Primers." "Photomicrography and Its Importance in the Paint Laboratory," A. Karsten. "Oil-Free Paint Media." "Urea-formaldehyde Resins—1. Plasticus." "Hydrogenation of Congo Copal," E. Mertens, L. Hellinckx, and C. de Hoffmann. "Old and New Nitrocellulose Combination Lacquers," F. Zimmer. "Varnishes for Electrical Purposes." Paint & Varnish Production Manager, December, 1937, pages 11, 18, 28, 31, 32.

Engine Design and Research

Aeronautics in 1937. Important developments in airplane-engine design are considered to be: large number of engines capable of using high-octane fuels employed by R.A.F.; progress in sleeve valve engines now produced in sizes up to 1375 hp.; and production of engines with two-speed superchargers. The review covers interesting features of the Rolls-Royce Merlin, deHavilland Gipsy, Blackburn Cirrus, Napier Rapier and Dagger, Bristol Mercury, Hercules, Pegasus XVIII, and Armstrong-Siddeley Genet, Lynx, Cheetah, Panther, and Tiger VIII. Engineer, January 14, 1938, pages 41–44, 52, 13 illus.

At the S.A.E. Meeting. Carburetion, manifolding, antiknock, fuel research report, fuel types for Diesels, air conditioning, Douglas four-engined planes, and Diesels in air service. Abstracts of papers and some of the discussions. Automotive Industries, January 22, 1938, pages 111–117, 129, 8 illus.

Cooling the Rotor of the Turbo-Supercharger. J. Oderfeld and J. Sachs. Rateau-Potez, Lorenz, Brown-Boveri, and General Electric processes proposed for cooling the rotor of turbo superchargers are explained and the authors' invention is described (Polish Patent No. 23,525). The ring of the blades is enveloped by a rim furnished with circular vanes which turn toward the interior of a collector full of air, the movement of which is in the same direction as the rotor rotation. Les Ailes, January 6, 1938, page 7, 7 illus.

Sees Radical Changes in Future Aircraft Engines. J. H. Geisse. "The British have a new rotary-valve engine about which information is now available. Compression ratios of 11 and 12.1 are claimed permissible with ordinary automobile spark plugs and gasoline, and fuel consumption is said to be at the phenomenally low figure of 0.32 lb. per hp.-hr." Possibilities for excelling the conventional engine with some unusual types. Brief abstract, Washington Section paper. S.A.E. Jour., January, 1938, page 24.

Accessory Knock Suppressors. L. B. Kimball. Valve developed by Fuel Development Corporation for use with Anilol, its antiknock fluid. As soon as predetermined manifold pressure is reached, the valve opens to admit Anilol to the engine, increasing the flow as requirements increase, so that octane requirements of the engine are always supplied. Under take-off conditions carburetor icing would be impossible as Anilol would be flowing through the carburetors. Tests described were carried out on a Wasp C engine, on the nose motor of a Ford trimotor, and on a DC-2 airplane equipped with Wright Cyclones. DC-3 installations and use of Anilol as a propeller deicer are discussed. S.A.E. Preprint for Meeting, January 10–14, 1938, 6 pages.

Aero Engines—Today and Tomorrow. Modern tendencies in aircraft-engine design and means employed for obtaining higher power, advantages of the two-row radial and the H- and X-shaped engines, cannon possibilities of the latter, the horizontally-opposed engine, ducted cooling, and air cooling versus liquid cooling. Two-row radials delivering 2000 hp. at altitude within four or five years are predicted. Even now Alvis is claiming 1700 hp. take-off power for its Alcides. References are made to the 16-cylinder double-octagon Bristol engine developing 1020 hp. at 6000 ft. which was built in 1931, new engines now in production, the 24-cylinder Napier Dagger III to power the Hawker Hector Army Cooperation plane, and the projected 20-cylinder 5-bank 1000-hp. radial mentioned by Fedden. Drawing of a hypothetical Merlin installation showing placing of units and photographs of other engines and parts are included. Flight, December 2, 1937, pages 524–538, 18 illus.

Analysis of the Accessory Drive Problem of Aircraft Engines. R. P Lansing. Auxiliary 4-cylinder double-opposed prestone-cooled 30-hp. engine developed as an accessory drive for a large transport now under construction is briefly described. Design requirements for a 20-hp. accessory drive unit of the "gear-box" type are discussed in detail. Various means of driving the gear box are compared including direct engine drive and drive by hydraulic motor, by exhaust-driven turbine, and by generator mounted on the engine. Location of the airplane accessory-group drive is taken up and advantages of removing them from the main engines are pointed out. S.A.E. Preprint for Meeting, January 10–14, 1938, 10 pages.

Design of Cowlings for Air-Cooled Aircraft Engines. D. H. Wood. Fundamental relations between pressures and velocities of the external and internal air flows in their relation to quantity of air available for cooling and effect on drag. N.A.C.A. experimental results. The exit is considered as the important part for an efficient cowling and control of air flow, and a procedure is given for designing an efficient skirt and inner cowl which form the exit. A new type of cowling providing more flow of air for cooling on the ground is discussed. The inline aircooled engine is also considered. Discussion by O. Schey, B. Pinkel and H. H. Ellerbrock, Jr., included. S.A.E. Jour. (Trans.), December, 1937, pages 581–595, 15 illus., 1 table, many equations.

Analysis of Improvements in Aviation Spark Plugs. T. Tognola and A. W. DeChard. Tests and apparatus used in the development of the Scintilla Bendix 5AFL spark plug. Ground electrode or shell baffle and core nose designs; tests of electrode materials under heat and subject to action of lead-content gas vapors and test equipment; tests of voltage required to break down various air-gap settings with various designs of core and shell electrode patterns; tests of finned and unfinned plugs; and testing spark plugs in a pressure bomb. S.A.E. Preprint for Meeting, January 10–14, 1938, 13 pages, 13 illus.

Power Plant Trends. G. J. Mead. Paper and discussion following. Jour. Royal Aeronautical Soc., November, 1937, pages 997–1024 and (discussion) 1024–1041, 22 illus., 1 table.

The Problem of Ring Sticking in Aviation Engines. O. C. Bridgeman. Control of temperature keeping it below the critical value for the type of aviation oil available is perhaps the most certain solution. As horsepower output per cubic inch of displacement is increased, every effort should be made to increase the rate at which heat is removed from the piston. Effects of oil characteristics, operating conditions and ring design features are pointed out. More adequate laboratory test methods for ring sticking, more information on piston temperatures, research on design of piston rings and grooves, and standardization of ring characteristics are urged. S.A.E. Jour., (Trans.), December, 1937, pages 545–547.

Recent Work in Vibration. J. P. Den Hartog. Most notable development was the introduction of turned dynamic dampers to counteract torsional vibration in radial aircraft engines. Short review on vibration with long bibliography. Jour. Applied Mechanics, September, 1937, pages A136–A137.

Turbulence in Internal Combustion Engines. W. T. David. Cylinder turbulence resulting from rapid entry of the charge into the cylinder, has little influence upon rate of heat loss during the explosion-expansion stroke. Way in which turbulence may be set up during combustion is considered and influence of turbulence on flame propogation discussed. Engineer, December 31, 1937, pages 733–734, 9 illus.

Vagaries of Internal Combustion. J. Small. First issue—Contrast of types of engines; homogeneity of charge in spark-ignition engines; vaporization in the gasoline engine; characteristics of the ignition and combustion process; detonation; ignition quality, lag, and temperature; and detonation, dopes, and the nuclear theory.

Second issue—New Bauer cylinder pressure indicator combining optical and mechanical means is described in a review of apparatus for investigating combustion. Discussion includes: Secondary combustion effects and combustion experiments; ignition lag in oil engines; combustion air and fuel distribution; starting conditions; turbulence in oil engines; effects of temperature distribution and oil distribution; and vaporization and ignition in oil engines. Institution of Engineers and Shipbuilders in Scotland paper. Engineer, December 3 and 10, 1937, pages 643–644 and 668–669, 19 illus.

DIESEL ENGINES

The Diesel as a High-Output Engine for Aircraft. E. G. Whitney and H. H. Foster. With present technique the 4-stroke-cycle Diesel can provide a maximum power for take-off equal to that obtainable from present gasoline engines using 100-octane fuel to maximum power advantage and can attain lower specific fuel consumption. The 2-stroke Diesel offers the possibility of greater power per unit size and weight than the 4-stroke at expense of increased fuel consumption. Analysis of results obtained at the N.A.C.A. Laboratory with the 4-stroke and 2-stroke Diesel. S.A.E. Preprint for Meeting, January 10–14, 1938, 20 pages, 14 illus.

Engine Testing

A Mountain Test Plant? French experiment of testing aircraft engines at actual instead of imitation altitudes. Brief editorial commending the establishment of an engine test plant at Mount Lachat. Flight, January 13, 1938, page 28.

Program of Tests at the Mont Lachat Station. G. Mahoux. Engine tests to be undertaken in the French high-altitude engine laboratory are discussed. Les Ailes, November 25, 1937, page 7.

Power Tests in Flight. C. E. Stryker. Torque indicator developed by Pratt & Whitney is described in detail. Performance data show effect of cowl flaps, fuel consumption with altitude, and effects produced by varying the mixture in an experimental engine. Use of torque indicator in determining operating characteristics for maximum range, static tests to measure static thrust, and value of device in checking ignition are discussed. Long abstract of S.A.E. paper by A. L. MacClain and R. S. Buck entitled "Flight Testing with an Engine Torque Indicator." Western Flying, January, 1938, pages 18–22, 38, 3 illus.

Quiet Please. New Pratt & Whitney four-unit engine and propeller test house where 3000-hp. engines and 23-ft. diameter propellers may be tested. Description of test house refers to sound proofed control room, cable suspension for engine mounts, and air supply system. Western Flying, January, 1938, pages 23 and 38, 3 illus. U.S. Air Services, January, 1938, page 21, 1 illus. Les Ailes, December 23, 1937, page 8, 1 illus.

Photograph only. Aviation, January, 1938, page 53, 1 illus.

Engine Installation

Engine Installation and Related Problems in Large Aircraft. I. L. Shogran. Engine installation problems arising during development of the Douglas DC-4 four-engined transport landplane having 60,000 lb. gross weight and accommodating 42 passengers and crew of five. Arrangement of engine mounts and nacelles; location of engine controls in the cockpit; oil and fuel systems; control system; collector ring and exhaust system; cowling; induction system; auxiliary engines; and air inlet and outlets for oil coolers. S.A.E. Preprint for Meeting, January 10–14, 1938, 8 pages.

Engines

Britain's Aero Engines. Data on 44 current British aircraft engines are given in a table and a few details of the products of the Alvis, Armstrong-Siddeley, Anzani, Aspin, Bristol, British Salmson, Chilton, Cirrus, Coventry Victor, Napier, J.A.P., Pobjoy, Rolls Royce, Scott, Villiers Hay, and Wier companies are described. Flight, December 2, 1937, pages 544a–544l, 30 illus., 1 table.

Continental Series A-50 Engine. New direct-drive horizontally-opposed aircooled two-bank four-cylinder aircraft engine producing a 25-percent increase in horsepower over the A-40 engine of substantially the same weight. Maximum fuel consumption at 50 hp. at 1900 r.p.m. is 4.5 gal/hr. Long description. Aero Digest, January, 1938, pages 50, 52, 4 illus. Aviation, January, 1938, pages 34, 67–68, 2 illus., 1 table. Western Flying, January, 1938, pages 30, 32, 2 illus., 1 table.

Fruits of 1937. Section devoted to progress in aircraft engines is brief and refers to the Bristol Hercules, Armstrong-Siddeley Tiger VIII, and the Bristol Pegasus XVIII having two-speed superchargers, the Rolls-Royce Merlin II, and the Napier Dagger E.108 24-cylinder. Still to be type tested are the Alvis Maconides, Pelides and Alcides high-powered two-row radials. Small engines are also mentioned. Flight, December 30, 1937, pages 638–641, 6 illus.

Engines of the Breda 88. Piaggio P-XI develops 1200 hp. at take-off, 1000 hp. at rated height and 875 hp. on the ground. Few details. Les Ailes, December 23, 1937, page 6.

German Engines. Junkers Jumo 210 12-cylinder inverted engine developing 680 hp. at 3700 meters. Junkers Jumo 211 12-cylinder inverted with two-speed supercharger, developing 1025 ho. at 1700 meters. Daimler-Benz D.B. 600 12-cylinder inverted developing 950 hp. at 4000 meters. Bramo Fafnir 323 J 9-cylinder radial developing 850 hp. at 4200 meters. B.M.W. 14-cylinder radial of 1500 ho. Few figures for all but the last. Les Ailes, December 23, 1937, page 8.

A New 2-Cylinder 38-Hp. Engine. New Polymechanique 2-Al two-cylinder opposed aircooled engine recently passing tests at Chalais Meudon. Short description of design. Les Ailes, December 23, 1937, page 12, 2 illus.

Seven-Cylinder Lycoming. New R-530-D 7-cylinder radial aircooled engines rated at 210-220 hp. at 2300 r.p.m. for take-off and 190–200 normal maximum hp. at 2100 r.p.m. Construction and specifications. Aviation, January, 1938, page 38, 2 illus , 1 table.

The Aspin Engine. L. Mantell. Detailed technical consideration of a unique design of head incorporated in the four-cylinder horizontally-opposed aircraft engine developing 80 to 90 b.hp. at 4500 r.p.m. and having a compression ratio of 10.2 to 1. In tests a single-cylinder motorcycle engine ran for over 2000 hours at various loads and speeds, but always exceedingly high without showing any undue wear.

The single rotating member constituting that part of the head exposed to the combustion flame, functions simultaneously as a rotary inlet and exhaust valve, a charge "turbulator," and a hot-spot shield. While rotating it carries the whole of the peak thrust reaction reaching at maximum load about 1900 lb./sq. in. Cooling of the rotating head is perfect and power absorbed in driving is trifling. Construction, cooling, combustion process, and explanations for the very early completion of combustion, and scavenging effects imparted by the local centrifugal action of the cell due to whirl. Automobile Engineer, January, 1938, pages 3–6, 8 illus.

New 50-Hp. Menasco. M-50 four-cylinder horizontally-opposed L-head aircooled aircraft engine develops 50 hp. at 2550 r.p.m. and weighs 156 lb. Few details. Automotive Industries January 22, 1938, page 99, 1 illus.

ACCESSORIES

Anti-Vibration Mountings. Two types of Metalastik mountings for inline engines are illustrated and reference is made to the new rubber-to-metal bonding process. Flight, January 13, 1938, page 48, 2 illus.

Compressed Air Starting. Garelli Avio compressors, used for starting on all aircraft engines of the Italian Regia Aeronautica, are undergoing British Air Ministry tests. A small single-cylinder two-stroke motor drives a single-cylinder compressor on the same crankcase. The compressor in its turn charges an airbottle to a pressure which can range from 18 to 25 atmospheres in 30 to 80 seconds. The motor can be obtained with a centrifugal governor to work radio, and will run for some hours on a cupful of gasoline. Short description. Aeroplane, January 5, 1938, page 26.

Fuels and Lubricant

Antiknock Changes Delayed; Custom Made Lubricants. C. O. Wilson. "The Effect of Oil Characteristics on Wear in Aviation Engines," O. C. Bridgeman and M. L. Leidig. Brief abstract of S.A.E. paper giving that part which deals with the problem of choosing lubricants of satisfactory characteristics for use in aviation engines. Brief abstracts of other S.A.E. papers included were previously abstracted from preprints. Oil & Gas Jour., January 20, 1938, pages 25–26.

Aircraft Radio

Reducing Radio Congestion. Purpose of the omni-directional beacon at Mitcham is to provide D/F and homing facilities for machines up to and after the moment at which they are ready to enter the Croydon controlled zone. Brief note Flight, January 13, 1938, page 44.

The Ultra-Short-Wave Guide-Ray Beacon and Its Application. E. Kramar and W. Hahnemann (C. Lorenz. A.G.). Fundamental principle and technical improvements of the ultra-short-wave instrument landing system in Europe, experience in the operation of the beacon, conditions of inversion of signals to avoid clicking, causes and avoidance of split beams, and restriction of disturbed zones are discussed. Ultra-short waves are treated on the basis of the theory of combining reflection and diffraction on the earth with respect to their application to long-range navigations. Experiments made in Australia giving very satisfactory results are described and examples are given for producing four beams in any desired direction and for introducing the landing beacon in the long-range navigation system. Properties of the ultra-short-wave system of navigation are considered in comparison with the use of long-wave beacon to the advantage of the former. Inst. Radio Engrs., Proc., January, 1938, pages 17–44, 27 illus.

Aero Radio Digest. Springer Type AR-3 lightweight aircraft radio receiver offered with two types of dynamotor, AR-70 headset, and 63-MR storage battery. Sperry-Stark gyroscopic airport orientator using a removable airport chart and showing its relation to the geographical north and course pattern of the adjacent range beacon. Western Electric Type 3-A rotatable loops used by United Air Lines. Universal dynamic airport microphone. Federal Communications Commission regulations on frequency measurements. Burgin radio range projector for solving problems of radio navigation either in flying the radio ranges or in direction finding. Aeronautical Radio static limiter filter device placed in series with headphones to cut off peak voltages. Descriptions of this equipment. Aero Digest, January, 1938, pages 54, 56, 7 illus.

The Air-Track System of Aircraft Instrument Landing. G. L. Davies. Development of radio equipment for the Air-Track system; limitations of the Newark installation; results accomplished by Washington Institute of Technology in the elimination of these limitations and refinement of equipment. Present portable unit and ground and aircraft equipment described in detail. S.A.E. Preprint for Meeting, January 10–14, 1938, 18 pages, 5 illus.

Aircraft Radio. Western Electric rotatable loop. Fairchild RC-4 radio compass with streamlined loop. Brief descriptions of equipment, and reviews of "Aircraft Radio Information" by RCA, and the Federal Communications Commission ultra-high aircraft frequency regulations. Aviation, January, 1938, pages 45, 49, 3 illus.

Experiments with Underground Ultra-High-Frequency Antenna for Airplane Landing Beam. H. Diamond and F. W. Dunmore. Experiments for locating the landing beam in the center of an airport in order to secure a steeper approach path and to provide for landing service for different wind directions. Effect of proximity of the ground to the transmitting antenna upon the low angle distribution of energy in the radiated field and upon polarization of the field, and approximate mathematical analysis for the mechanism of setting up a landing path when the transmitting antenna is below the ground surface. Inst. Radio Engrs., Proc., December, 1937, pages 1542–1560, 11 illus., 2 tables, 12 equations.

The Practical Use of Radio as a Direct Aid to the Landing Approach in Conditions of Low Visibility. Squadron Leader R. S. Blucke. Lorenz track beacon system and the Hegenberger radio compass system. Procedure and equipment used in both systems are described in detail. A pilot's impressions of the two systems and fog impressions are given. Factors governing satisfactory blind approach from the pilot's point of view are briefly discussed. Royal Aeronautical Soc., Preprint for Meeting, January 10–14, 1938, 20 pages, 21 illus.

Radio Network and Practice of Pan American Airways. H. W. Roberts. Pan American does not employ radio range beacons or localizers. In long range radio navigation direction finding is done from the ground with large direction finders on shore triangulating the position of the craft along its route. Both loop and Adcock-type direction finders are used. For the rest,

radio navigation is done almost exclusively by direction finders aboard aircraft, modified Bellini-Tosi and null-type loop direction finders being used. Radio training for its personnel is described. To be continued. Aero Digest, January, 1938, pages 32, 34, 4 illus.

Unbending the Beams. Progress on modernized airways with special reference to winter operations. Report on present status of the Bureau of Air Commerce projects scheduled for 1937 and the Bureau's program in regard to radio aids to navigation. Aviation, January, 1938, pages 20–21, 67, 3 illus.

Meteorology

Transatlantic Meteorology. P. M. Cowan. Work of the Weather Bureau at the Botwood base, Newfoundland, in supplying meteorological information during last season's Atlantic experiments, forecasting difficulties and accuracy, and radio cooperation. Flight, January 6, 1938, pages 4–7, 7 illus., 1 table.

Weather Squadrons. Lt. R. M. Losey. Necessity for the Air Corps Weather Service to provide forecasts for flight planning; present status of meteorology; organization and training methods of the Weather Service; weather station operation; mobile units; and employment of the Weather Service in tactical operations. U.S. Air Services, January, 1938, pages 10–12, 35, 3 illus.

On Pilot Balloons and Sources of Light for High-Altitude Upper-Wind Observations. Major W. H. Wenstrom. Research discussed was begun in 1934 in response to military meteorological problems. Characteristics of the 6-in., 12-in. and 16-in. pilot balloons; various balloon lights including four-, six- and eight-candle lanterns, three-watt electric light, acetylene light, pyrotechnic flare experimented with at the Strato camp, June, 1935, and recent developments and difficulties; observational technique in regard to theodolite considerations; and possibilities for high-altitude upper-wind facilities. Monthly Weather Rev., September, 1937, pages 326–331, 4 illus.

Faster Ascending Pilot Balloons. A. P. Rehcock. New DAREX No. 100 balloon having an ascension velocity of 6 meters/second and bursting diameter of over 7 ft. allowing the balloon to reach more than 40,000 ft. before bursting. Am. Meteorological Soc., Bul., November, 1937, pages 356–359, 2 illus., 1 table.

Aeronautical Industry and Production

1938 Outlook Most Promising. Military aircraft sales jumped 101.4 per cent to $23,498,482, represented by 541 units, in the first nine months of 1937. More than 510 American aircraft and 870 engines were exported. Short editorial comment. Aero Digest, January, 1938, page 40.

2757 Planes Produced. Aeronautical production statistics in the United States. Aero Digest, January, 1938, page 91.

The Ancillary Industry. Easy-reference encyclopedia of over 300 firms that make their contribution to British aircraft manufacture and operation. Robertson oil cooler for 1000-hp. aircraft engines having hot-oil jacket and automatic control valve, Marconi transmitter developed especially for transatlantic flights, and Lockheed constant-speed propeller control are illustrated. Flight, December 2, 1937, pages 545–566, 14 illus.

Directory of the Manufacturers of Aircraft and Engine Machinery American manufacturers, their addresses and products are listed both according to name and product. Aero Digest, January, 1938, pages 72–88 and 62–71.

Equipment and Procedure for Constructing Four-Engined Airplanes. Boeing production methods used in constructing the 72-passenger Model 314 Pan American Clippers for transoceanic service, and the Model 307 33-passenger transports as well as the Air Corps bombers. Aero Digest, January, 1938, pages 17–19, 14 illus.

"Flow Processing" Method of Aircraft Production. G. E. Barton. New method of routing and traffic control recently put into operation by the Aeronautical Corporation of America. Aero Digest, January, 1938, pages 28, 30, 8 illus.

Hamilton Standard Propeller Production. Operations in the manufacture of controllable and constant-speed propellers. Aero Digest, January, 1938, pages 20–21, 7 illus.

Jig and Hand Operations on the "Safest" Plane. L. Stearman. Production technique selected for the Stearman-Hammond "Y" airplane. Am. Machinist, January 12, 1938, pages 18–21, 9 illus.

News from Tokyo. A tendency is reported on the part of Britain, America, France, Germany, Italy, and Soviet Russia to refuse shipments to Japan of precision machines and instruments for aircraft manufacture or to divulge the technique of their construction. A proposed Japanese research institute equipped for research and development in this particular field, as well as in aeronautical research, is urged. Brief note. Automotive Industries, January 8, 1938, page 43.

Prospects for 1938. Upward trend of aircraft sales will continue at least through 1938 but increase will be modest and due, primarily, to the fact that the Army should receive twice as many planes this year as they did last. Navy will not get as many planes, airlines will not buy as extensively, and war in China will interfere with our export trade. Army may possibly return to the policy of purchasing 100 per cent of spare engines and engine sales would materially increase. Short editorial. U.S. Air Services, January, 1938, page 9.

The Shadow Factories. Seven British shadow factories are now complete and are employing about 5800 persons. Attention has been given and is continuing to be given to the question of vulnerability of these factories to air attack. Brief reference. Aeroplane, December 8, 1937, page 689.

Air Forces

Some Figures on Aviation in Other Countries. General Weygand. Position of national defense in Germany, Italy, U.S.S.R., England, and France. Les Ailes, November 25, 1937, page 11.

FRANCE

Report of the French Naval Aviation Maneuvers. Commandant A. Langeron. First of a series of articles describing various phases of the recent maneuvers. Les Ailes, December 2, 1937, page 11.

What France Proposes to Do. French Air Estimates for 1938, amounting to 1,481,000,000 francs (roughly £10,000,000), were passed by the French Chamber of Deputies. Increase is 810,000,000 francs (about £5,500,000) over the 1937 Estimates. Editorial comment criticizes the French Air Minister's statement that French bomber and pursuit prototypes reach a speed of 300 m.p.h. which is faster than any British or German airplanes, and points out that several airplanes going into the R.A.F. could beat 300 m.p.h. and that the fastest British fighters are reputed to do 350 m.p.h. Aeroplane, December 29, 1937, page 803.

GERMANY

On That Colonial Question. C. G. Grey. "My own idea, and it is shared by many people, is that the Germans do not want colonies as a commercial asset. They want them as a matter of prestige." Question of whether a profit could be derived from the colonies wanted by Germany, and ways in which handing over bits of the world to be "properly governed" by Germany will affect the airlines. Aeroplane, December 29, 1937, pages 805–807, 2 illus.

GREAT BRITAIN

Air Raid Precautions. C. M. McAlery. Duties of the British Air Raid Precautions Department, precautions procedure, responsibilities of local air-raid wardens, and parliamentary debate on the Air Raid Precautions Bill. Aeroplane, December 29, 1937, pages 811–812.

One-Job Pilots. New British Air Ministry policy of training short-service pilots in one class of unit only throughout their service on the active list. Short note. Aeroplane, December 8, 1937, page 694.

A Queen Bee Unit at Work. A. E. Barlow. Account of various maneuvers of the British Fleet with the radio-controlled airplane as a target. In recent maneuvers the "Southampton's" catapult caused the erratic behavior of two Queen Bees as it had a slightly greater "g" than the older type of cruiser. Dive bombing is being practiced. Procedures for controlling the Bee and for assessing the accuracy of the shooting are briefly outlined. Aeroplane, December 8, 1937, pages 696–697, 3 illus.

A Service Long Range Unit. R.A.F. Long-Distance Flight is to be formed to investigate the possibility of increasing operational range of Service aircraft and to develop an existing type for long-range work. Three Vickers Wellesleys with Bristol Pegasus motors will be allotted to the Flight. Brief note. Aeroplane, December 1, 1937, page 664.

The Balloon Barrage. Recruiting of personnel of the new Balloon Barrage Squadrons of the Auxiliary Air Force is reported. Each squadron will need about 400 men and of the 9 squadrons to be raised, three will be stationed in the London area. Brief reference. Aeroplane, January 5, 1938, page 12.

The Royal Air Force in 1937. C. M. McAlery. Outstanding feature was the way in which junior officers of the R.A.F. handled commands which would not, in normal conditions, have been their responsibility for several years to come. Six new types of airplanes came into the Service in quantities and two or three old types were withdrawn. Four new Groups were organized, 15 new stations were opened, 35 new squadrons (23 bomber, and three new Auxiliary Squadrons) were formed. Appointments, operations and exercises, flying-boat squadron operations, displays, ceremonials, and casualties are reviewed. Aeroplane, January 5, 1938, pages 9–11, 5 illus.

The Suez Canal. A new and very good station will be established for the R.A.F. on the banks of the Suez Canal. Air squadrons in Iraq are being withdrawn from the Tigris to Dhibban on the Euphrates where an air station of the most modern description is nearing completion. Brief editorial comment. A second brief note gives a few details of the Dhibban Station. Flight, January 13, 1938, pages 28, 40.

Training an Air Force Pilot. Air Vice-Marshall L. A. Pattinson. Controversial subject of bad-weather service flying, discussed at a meeting of the Royal United Service Institution, and the new system of training. Flight, January 13, 1938, page 42.

PARAGUAY

The Position in Paraguay. "The Paraguayan Air Force is practically without flying equipment." Pilots are in Europe to take delivery of Caproni bomber-reconnaissance machines and receive instructions. Brief note. Flight, January 13, 1938, page 41.

U. S. A.

Air Tactics. Brig. Gen. H. C. Pratt. Offensive and defensive tactics of Bombardment Aviation are discussed in detail as well as tactics of Attack, Pursuit and Observation Aviation. References are made to air tactics employed in the world war, in Ethiopia and in Spain in comparison with the present tactical methods advocated. The Air Corps Tactical School, its cooperation with GHQ Air Force, and its curriculum are described. Western Flying, January, 1938, pages 10–13, 34, 36, 53, 8 illus.

Woodring Recommends. "Our goal in airplane strength is 2,320 modern, serviceable planes, to be attained not later than June 30, 1940." Abstract of 1937 report made by Secretary of War Woodring to the President. Western Flying, January, 1938, pages 24–25.

Air Warfare

Bombing the Bomber. W. Maclanachan. "Antiaircraft" bomber airplanes to be used in an emergency as auxiliaries to fighters. Fast bombers such as Blenheims are suggested for dropping "aerial depth charges" on raiding bombing formations. Possibilities, effects, and training of fighter-pilots on twin-engined airplanes are considered in a short article. Editorial note states that antiaircraft bombing by fighters dates from early war days, although, excepting perhaps in America, tactics and equipment have not been developed parallel with aerial gunnery. Flight, January 6, 1938, pages 19–20, 1 illus.

Armament

Bombs and Bombs. Capacity of a medium bomber for starting 150 fires, low efficiency of the incendiary bombs which were used over Madrid, and armor-piercing projectiles as unsuitable for dropping from airplanes in most cases. Short editorial. Flight, December 2, 1937, page 532.

Deflection. Deflection of bullets fired at an angle to the line of flight is a problem coming into prominence during firing trials from some of the French multiplace combat airplanes. Although some most impressive arcs of fire were obtainable on paper, deflection of bullets fired broadside very seriously detracted from their fighting value. Logical step is to increase the muzzle velocity of the bullets. Short note. Flight, January 6, 1938, page 22.

The Four Winds. A Fairchild 24 light cabin monoplane with Ranger inverted engine has been sold to the Oerlikon Machine Tool Works at Zürich. A dummy cannon is fitted for demonstration purposes. Brief reference. Flight, January 13, 1938, page 39.